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Issued May 26, 1910.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF SOILS—BULLETIN NO. 66.

MILTON WHITNEY, Chief.

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FERTILIZERS FOR WHEAT SOILS.

BY

MILTON WHITNEY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Soils,
Washington, D. C., October 28, 1909.

Sir: In order to establish certain fundamental principles regarding the effect and efficiency of fertilizers on soils used for wheat, I have had compiled all the available results of plat tests carried out by the experiment stations. The tests on any given plat have usually been for single seasons, and this has left some uncertainty as to the actual efficiency and cumulative effect from year to year if the fertilization should be continued annually for a number of years on the same soil. For this reason there has been included a similar consideration of the records available covering some of the long-time investigations made in this country and in England. These latter results show that the large number of short-time experiments made in this country by the various experiment stations are a reliable indication of the relative efficiency of different fertilizer materials.

It is believed that this matter will be of considerable interest to the farmers of this country, and I therefore have the honor to recommend that the article be published as Bulletin No. 66 of the Bureau of Soils.

Very respectfully,

Milton Whitney,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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FERTILIZERS FOR WHEAT SOILS.

INTRODUCTION.

The experiment stations have recorded in their reports and bulletins the results of 3,227 tests of substances applied to wheat soils, that is, soils upon which wheat is to be grown.

Each test represents some single substance used alone or some combination of substances and every result has been taken where the yield of a "check" or unfertilized plat has been recorded, where the amount of each substance per acre could be determined, and where the yield or increased yield per acre of wheat could be found. The results have been accepted whether the plats were located on the station farm or the experiments were carried out by cooperating farmers. No experiments from any source, not accepted and adopted by the stations and rendered in their official publications, are considered in this bulletin.

NUMBER OF EXPERIMENTS.

The following table gives the number of tests recorded for each year:

Number of individual plat tests on wheat soils by years.

Year.	Number.	Year.	Number.	Year.	Number.	Year.	Number.
1869	32	1884	159	1893	138	1902	202
1870	38	1885	80	1894	144	1903	70
1876	4	1886	247	1895	86	1904	74
1877	5	1887	135	1896	131	1905	52
1879	10	1888	115	1897	187	1906	21
1880	8	1889	179	1898	49	1907	14
1881	118	1890	186	1899	104		
1882	83	1891	127	1900	145	Total	3,227
1883	106	1892	110	1901	70		

The following table gives the number of tests recorded for each State:

Fertilizer plat tests on wheat soils, arranged according to the number of individual tests made in each State.

State.	Number.	State.	Number.
Pennsylvania	955	South Dakota	35
Ohio	764	West Virginia	34
Tennessee	441	South Carolina	27
New Jersey	160	California	27
Maryland	144	North Dakota	14
Indiana	118	Minnesota	12
Virginia	113	Utah	12
Kentucky	87	Alabama	12
Illinois	60	Delaware	11
North Carolina	58	Arkansas	8
Missouri	55	Oklahoma	4
Kansas	39		
Texas	37	Total	3,227

Yield of wheat in bushels per acre on unfertilized plats when more than one such plat is given.

Yield.	Yield.	Yield.	Yield.	Yield.	Yield.	Yield.	Yield.	Yield.	Yield.
Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
0.1	0.5	4.2	2.0	9.4	10.8	11.2	20.2	27.1	28.0
.2	1.3	5.5	6.0	9.7	18.1	18.5	20.9	30.8	32.7
.2	1.6	5.6	9.3	12.6	**14.5**	19.3	24.2	31.2	33.7
.3	3.5	**5.1**	9.5	**10.6**	8.8	19.9	**21.8**	31.5	34.8
.6	4.7	4.4	10.1	10.6	10.3	21.1	17.0	31.5	34.9
.7	**2.9**	5.3	**7.4**	12.5	12.8	**18.0**	23.2	31.8	35.1
.7	1.4	5.8	5.9	**11.5**	13.1	15.7	23.5	32.0	36.2
.7	2.1	6.2	6.1	.7	13.9	16.0	24.8	35.3	41.9
.7	2.1	7.6	6.7	12.4	14.0	22.4	25.0	**31.4**	43.4
.8	2.2	**5.9**	7.0	14.0	15.0	**18.0**	**22.7**	28.9	44.5
.9	2.6	4.2	7.5	15.3	15.6	13.5	15.9	34.1	44.8
1.0	2.7	8.1	7.7	16.6	15.8	17.5	23.3	**31.5**	45.1
1.2	2.8	**6.3**	7.8	**11.8**	16.4	18.0	23.7	25.2	**37.9**
1.5	3.2	3.9	8.0	9.5	16.5	18.2	23.7	26.3	33.6
.7	3.6	7.6	8.3	11.7	16.5	19.0	29.2	27.1	36.2
.2	7.2	8.1	8.7	14.7	16.5	20.4	**23.2**	27.2	37.6
.2	**3.0**	**6.5**	8.9	**11.9**	18.6	20.8	17.9	31.0	38.9
.5	1.7	4.4	**7.5**	9.6	**14.6**	20.9	24.7	31.3	39.0
.7	2.5	5.1	1.6	11.2	10.3	22.2	25.4	31.6	42.0
.7	2.5	5.3	6.4	12.6	13.8	22.2	25.4	31.9	**37.9**
.8	2.5	5.8	6.7	13.5	14.8	**19.3**	25.9	32.7	38.4
1.2	2.8	6.2	10.6	13.9	17.2	19.4	**23.9**	32.9	40.7
1.3	3.3	7.1	12.3	**12.2**	20.2	19.4	22.2	33.6	41.5
1.4	3.5	7.7	**7.5**	10.7	**15.3**	19.4	25.4	34.2	42.5
3.5	3.5	8.5	6.6	11.6	13.9	**19.4**	26.2	34.7	43.6
1.1	3.8	9.0	7.2	13.2	14.0	16.2	26.8	34.9	45.4
1.0	4.0	9.2	10.0	13.7	14.1	16.5	27.2	35.9	**42.0**
1.1	4.1	**6.9**	**7.6**	**12.3**	16.9	17.2	27.8	40.1	36.7
1.1	4.4	3.7	4.8	8.8	17.5	18.3	28.1	**31.9**	37.8
1.3	5.2	4.3	5.0	9.2	**15.3**	19.3	28.6	32.5	40.5
1.1	**3.2**	4.3	5.7	11.8	14.5	19.7	**26.4**	32.5	40.8
1.0	1.3	5.5	5.9	13.0	14.5	20.0	22.8	**32.5**	44.2
1.0	1.7	7.2	6.0	13.0	14.7	20.6	24.5	33.2	46.0
1.0	2.3	8.7	6.4	13.0	15.0	20.6	24.7	33.3	47.5
1.0	4.0	10.5	6.5	16.2	19.4	20.8	25.2	33.7	50.5
1.1	6.6	13.0	6.7	16.3	**15.6**	20.8	26.8	34.7	**43.0**
1.2	**3.2**	**7.1**	8.1	**12.7**	15.1	21.0	27.5	35.2	35.8
1.2	1.0	4.5	8.3	7.0	15.3	26.4	27.7	**34.0**	42.8
1.4	2.2	4.7	8.5	12.4	16.5	**19.8**	32.1	30.8	46.6
1.4	2.2	4.9	9.9	14.0	**15.6**	16.7	**26.4**	31.2	47.4
1.4	5.7	5.5	10.1	15.3	14.3	16.8	25.3	32.5	**43.2**
1.2	6.4	6.1	10.6	16.6	18.0	17.8	27.7	32.9	41.5
1.4	**3.5**	6.2	11.6	**13.0**	**16.2**	19.7	28.0	33.7	41.6
1.5	3.3	6.3	13.7	13.0	15.5	20.2	**27.0**	33.7	44.6
2.3	4.2	6.4	**8.0**	13.4	18.3	20.8	30.8	34.2	45.2
1.7	**3.7**	7.6	5.4	**13.2**	**16.9**	27.3	30.8	34.5	46.0
1.2	2.2	7.7	5.5	7.7	12.6	**19:9**	**30.8**	35.5	**43.8**
1.6	2.5	8.4	6.4	14.7	14.3	17.2	26.5	36.2	38.9
1.7	2.7	8.6	12.6	20.3	17.4	18.5	29.9	37.3	42.9
1.7	2.8	8.7	13.0	**14.2**	20.2	20.6	31.0	37.5	42.9
1.8	3.0	8.7	**8.6**	8.9	20.8	21.1	31.8	**34.2**	42.9
1.9	3.2	8.9	9.0	13.6	**17.1**	22.5	31.9	29.3	43.7
2.0	3.3	10.3	10.0	15.8	13.7	**20.2**	32.4	30.0	44.2
3.0	3.8	**7.1**	10.0	16.4	14.3	19.7	32.4	30.8	44.3
1.9	4.0	4.8	10.5	17.3	17.7	20.0	33.0	36.3	44.9
1.9	5.0	5.3	11.0	**14.4**	19.5	20.8	**31.1**	40.0	49.1
2.2	5.2	6.2	**10.1**		22.8	22.5	26.5	42.7	49.5
2.0	6.0	6.2	8.0		**17.6**	23.0	29.9	**34.8**	49.6
1.0	6.2	6.6	9.0			**21.2**	31.0		49.8
1.2	8.0	6.9	9.3			15.9	31.8		50.6
1.7	**4.1**	6.9	9.8			20.6	31.9		50.8
1.8	2.5	7.2	9.8			22.1	32.4		51.4
1.8	4.2	7.4	9.8			23.5	32.4		**46.2**
2.2	4.5	16.7	9.9			25.9	33.0		
2.3	5.5	**7.4**	12.2			**21.6**	**31.1**		
2.5	6.7		12.2						
3.5	**4.7**		14.2						
3.8			**10.4**						
4.8									
2.4									

YIELD OF CHECK PLATS.

The investigations have been made under a wide range of soils or of climatic conditions, or both, as measured by the yield of the unfertilized or "check" plats. The table on page 8 gives the individual and average yield of wheat on the check plats when more than one such plat has been used and separately rendered. It will be seen that these yields on the unfertilized soil range from less than a bushel to over 50 bushels per acre.

Unfortunately, owing to the generally inadequate description of the soils in the reports of these experiments, it was found impracticable to group and analyze the data with relation either to physical or chemical differences in the soils, and the grouping employed—natural productiveness as evidenced by yields on the unfertilized plats—was chosen as the best available.

It will be seen from this table that the yield of duplicate plats is not all that could be desired for scientific work of this character, and this natural variation in results must be borne in mind in interpreting or applying the results in the following tables, and decidedly less weight should be given to the results from a few experiments than to the averages of a great many.

Another fact that must be mentioned is that in a great majority of cases the tests have been for single years, or continued at most for two or three years in the same field, with two notable exceptions, one in Ohio which has been carried on continuously for fifteen years and one in Pennsylvania which has been carried on continuously for twenty-five years. Both of these experiments will be referred to in more detail in a subsequent part of this bulletin, when the question of the reliability of individual tests as compared with long-time series of experiments will be discussed more fully.

In computing the relative efficiency, from a commercial standpoint, of the several substances which have been used in the fertilizer tests on wheat soils some arbitrary value must be assigned to each which will represent as fairly as possible the average cost to the farmer in the several States. However, when these values for any reason do not represent local market conditions, the data contained in the subsequent tables are sufficient to enable a recalculation to be made on any new basis of value.

The values used in computing the commercial efficiency of fertilizers in this bulletin are given in the following table:

Valuation of fertilizer ingredients used in plat tests on wheat soils.

Ingredients.	Cost per ton.	Ingredients.	Cost per ton.
	Dollars.		*Dollars.*
Nitrate of soda	50.00	Magnesium oxide	(*a*)
Sulphate of ammonia	62.00	Sulphate of magnesia	(*a*)
Dried blood	40.00	Barium oxide	(*a*)
Acid phosphate	14.00	Sulphate of iron	(*a*)
Rock phosphate	9.00	Lime	6.00
Floats	8.00	Marl	.50
Basic slag	12.50	Gypsum	8.00
Ground bone	26.00	Soft-coal ashes	(*a*)
Muriate of potash	44.00	Salt	8.00
Sulphate of potash	60.00	Castor pomace	23.00
Nitrate of potash	50.00	Wheat bran	(*a*)
Kainit	12.00	Straw	(*a*)
Phosphate of soda	(*a*)	Tobacco stems	15.00
Iron-alumina phosphate	(*a*)	Wool waste	(*a*)
Phosphoral	(*a*)	Manure	.50
Boneblack	22.00	Cow manure	.50
Cotton seed	16.00	Cow urine with chaff	(*a*)
Cotton-seed meal	25.00	Hog manure	.50
Cotton-seed hull ashes	34.00	Hen manure	15.00
Tankage	26.00	Pea vines	(*a*)
Caustic potash	(*a*)	Compost	.50
Soluble silicate of potash	(*a*)	Commercial fertilizers	20.00
Wood ashes	5.00		

a Not valued.

For the purposes of this comparative study the value of wheat to the farmer has been taken as 90 cents per bushel, which is approximately the average farm price of wheat for 1908, as given in the Yearbook of this department for 1908, page 608.

SUMMARY OF RESULTS.

The following table gives a complete summary of the results of the fertilizer tests on wheat soils, the first column showing the total number of tests, the second column showing chances to obtain an increase with any fertilizer, the third column showing the actual range of crop increases recorded, and the remaining columns giving the amount and cost of fertilizer used, the amount and value of increase in crop attributable to their use, and the average gain per acre.

Results of fertilizer tests with wheat soils.

MINERALS SINGLY.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increase.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Nitrate of soda	103	2.8:1	−10.3 to 11.6	196	4.91	1.7	1.53	−3.38
Sulphate of ammonia	25	5.2:1	− 4.3 to 15.1	222	6.88	3.6	3.24	−3.64
Acid phosphate	192	3.9:1	− 5.7 to 21.4	326	2.28	3.5	3.15	.87
Rock phosphate	25	4.0:1	− 6.5 to 13.4	762	3.43	3.6	3.24	− .19
Floats	1	1.0:0	2.5	400	1.60	2.5	2.25	.65
Basic slag	14	13.0:1	− 0.9 to 15.6	578	3.61	6.5	5.85	2.24
Phosphate of soda	3	2.0:1	− 1.3 to 4.0	183	....	1.9	1.71	....

Results of fertilizer tests with wheat soils—Continued.

MINERALS SINGLY—Continued.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Iron-alumina phosphate	2	2.0:0	9.1 to 13.3	370	....	11.2	10.08	....
Phosphoral	1	1.0:0	1.4	185	....	1.4	1.26	....
Nitrate of potash	3	3.0:0	2.0 to 6.3	261	6.53	3.5	3.15	−3.38
Sulphate of potash	7	2.5:1	− 1.9 to 5.3	258	7.71	2.2	1.98	−5.73
Muriate of potash	114	1.1:1	− 7.6 to 12.5	141	3.11	.4	.36	−2.75
Kainit	21	2.5:1	− 4.8 to 10.8	394	2.37	1.4	1.26	−1.11
Cotton-seed hull ashes	5	4.0:1	− 1.3 to 3.9	374	6.36	1.7	1.53	−4.83
Caustic potash	2	1.0:1	0 to 2.9	900	....	[a]1.4	[a]1.26	....
Soluble silicate of potash	1	1.0:0	4.8	634	....	[a]4.8	[a]1.32	....
Wood ashes	6	5.0:1	− 0.5 to 14.1	1,607	4.02	4.3	3.87	− .15
Magnesium oxide	3	2.0:1	− 1.1 to 5.4	1,400	....	[a]2.5	[a]2.25	....
Sulphate of magnesia	3	3.0:0	2.0 to 4.7	200	....	[a]3.5	[a]3.15	....
Barium oxide	3	2.0:1	− 2.1 to 2.2	1,400	....	[a].2	[a].18	....
Sulphate of iron	1	1.0:0	0.3	50	....	[a].3	[a].27	....
Lime	130	2.4:1	− 6.0 to 16.7	2,826	8.48	2.2	1.98	−6.50
Marl	9	2.0:1	− 1.0 to 7.6	6,200	1.55	2.1	1.89	.34
Gypsum	93	0.6:1	−15.9 to 10.1	445	1.78	− .8	− .72	−2.50
Soft-coal ashes	3	0:3	− 2.1 to − 1.2	13,000	....	[a]−1.7	[a]−1.53	....
Salt	29	1.0:1	−12.3 to 12.3	1,174	4.69	.9	.81	−3.88
Total	799	2.0:1	....	....	4.13	2.0	1.80	−2.33

MIXTURES OF TWO MINERALS.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre. Used.	Fertilizers per acre. Cost.	Crop increase per acre. Bushels.	Crop increase per acre. Dollars.	Average gain per acre.
Nitrate of soda Acid phosphate	68	8.7:1	−4.0 to 21.7	169 258	6.03	6.7	6.03	0.0
Nitrate of soda Rock phosphate	1	1.0:1	− 3.2	300 400	9.30	−3.2	−2.88	−12.18
Nitrate of soda Sulphate of potash	2	2.0:0	2.2 to 2.7	100 200	8.50	2.4	2.16	− 6.34
Nitrate of soda Muriate of potash	72	7.0:1	−7.9 to 18.8	169 110	6.65	3.6	3.24	− 3.41
Sulphate of ammonia Acid phosphate	4	3.0:1	−5.4 to 12.8	268 253	10.07	3.2	2.88	− 7.19
Sulphate of ammonia Rock phosphate	4	1.0:1	−3.4 to 3.3	131 200	4.97	.2	.18	− 4.79
Sulphate of ammonia Sulphate of potash	2	2.0:0	0.6 to 3.5	225 175	12.22	2.0	1.80	−10.42
Sulphate of ammonia Muriate of potash	8	3.0:1	−4.1 to 8.0	205 116	8.91	1.7	1.53	− 7.38
Acid phosphate Sulphate of potash	3	2.0:1	−0.7 to 2.5	300 183	7.60	.8	.72	− 6.88
Acid phosphate Muriate of potash	185	5.8:1	−6.6 to 24.7	258 156	5.25	4.9	4.41	− .84
Acid phosphate Kainit	3	2.0:1	−0.5 to 11.1	240 240	3.12	3.6	3.24	− .12
Acid phosphate Caustic potash	2	2.0:0	4.6 to 6.7	350 1,400	....	[a]5.6	[a]5.04	....
Acid phosphate Gypsum	1	1.0:0	4.5	340 163	3.03	4.5	4.05	1.02
Rock phosphate Muriate of potash	3	0:3	−6.0 to − 1.9	250 100	3.32	−3.8	−3.42	− 6.74

[a] Not included in the total averages, as the cost of fertilizers is not given.

Results of fertilizer tests with wheat soils—Continued.

MIXTURES OF TWO MINERALS—Continued.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Rock phosphate Gypsum	2	2.0:0	5.2 to 6.3	255 344	2.52	5.7	5.13	2.61
Basic slag Gypsum	1	1.0:0	3.3	375 343	3.70	3.3	2.97	.73
Phosphoral Gypsum	2	0:2	−1.6 to −0.5	185 262	......	[a]−1.0	[a]−.90	....
Sulphate of potash Sulphate of magnesia	1	1.0:0	0.2	200 200	......	[a].2	[a].18	....
Sulphate of potash Lime	1	0.0:1	−0.9	200 200	6.60	−.9	−.81	−7.41
Sulphate of potash Gypsum	1	1.0:0	0.4	200 200	6.80	.4	.36	−6.44
Muriate of potash Gypsum	2	2.0:0	1.0 to 1.5	200 200	5.20	1.2	1.08	−4.12
Caustic potash Coal ashes	1	1.0:0	0.1	900	......	[a].1	[a].09	....
Wood ashes Sand	5	4.0:1	−0.8 to 8.0	2,000 10,560	5.00	2.8	2.52	−2.48
Salt Sand	4	1.0:1	−6.6 to 4.0	560 8,800	2.24	−.2	−.18	−2.42
Total	378	5.3:1	....	....	5.79	4.5	4.14	−1.65

MIXTURES OF THREE OR MORE MINERALS.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Used.	Cost.	Bushels.	Dollars.	Average gain per acre.
Nitrate of soda Acid phosphate Nitrate of potash	2	2.0:0	11.5 to 13.6	80 480 200	10.36	12.5	11.25	0.89
Nitrate of soda Acid phosphate Sulphate of potash	3	3.0:0	8.5 to 21.3	263 427 150	14.06	14.3	12.87	−1.19
Nitrate of soda Acid phosphate Muriate of potash	295	20.0:0	−3.0 to 29.4	261 249 135	11.25	8.9	8.01	−3.24
Nitrate of soda Acid phosphate Kainit	3	3.0:0	22.0 to 27.1	300 400 400	12.70	23.9	21.51	8.81
Nitrate of soda Rock phosphate Muriate of potash	14	1.8:1	−6.3 to 14.6	161 240 96	7.22	2.6	2.34	−4.88
Nitrate of soda Basic slag Muriate of potash	16	7.0:1	−3.7 to 21.9	180 210 108	8.18	7.7	6.93	−1.25
Sulphate of ammonia Acid phosphate Sulphate of potash	3	2.0:1	−2.6 to 6.9	350 967 317	27.12	1.5	1.35	−25.77
Sulphate of ammonia Acid phosphate Muriate of potash	158	51.7:1	−2.5 to 38.1	230 245 152	12.19	9.4	8.46	−3.73
Sulphate of ammonia Acid phosphate Kainit	3	3.0:0	14.7 to 33.6	226 400 400	12.19	27.3	24.57	12.38
Sulphate of ammonia Acid phosphate Caustic potash	2	2.0:0	11.1 to 11.2	700 350 900	......	[a]11.1	[a]9.99	....
Sulphate of ammonia Rock phosphate Muriate of potash	3	0:3	−5.6 to 0	150 200 75	7.20	−3.0	−2.70	−9.90
Sulphate of ammonia Muriate of potash Gypsum	1	1.0:0	13.3	145 100 344	8.07	13.3	11.97	3.90

[a] Not included in the total averages, as the cost of fertilizers is not given.

Results of fertilizer tests with wheat soils—Continued.

MIXTURES OF THREE OR MORE MINERALS—Continued.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Ammonium phosphate Acid phosphate Muriate of potash	1	1.0:0	14.3	120 160 100	....	[a] 14.3	[a] 12.87	....
Acid phosphate Sulphate of potash Gypsum	2	2.0:0	0.5 to 3.1	200 200 200	8.20	1.8	1.71	−6.58
Acid phosphate Caustic potash Coal ashes	1	1.0:1	6.7	350 900	....	[a] 6.7	[a] 6.03	....
Sulphate of potash Sulphate of magnesium Gypsum	2	2.0:0	0.7 to 2.9	200 200 200	....	[a] 1.8	[a] 1.62	....
Wood ashes Gypsum Salt	3	3.0:0	1.0 to 3.6	1,000 100 560	5.14	1.9	1.71	−3.43
Nitrate of soda Sulphate of ammonia Acid phosphate Sulphate of potash	1	1.0:0	5.0	100 168 200 100	12.11	5.0	4.50	−7.61
Nitrate of soda Acid phosphate Sulphate of potash Gypsum	2	2.0:0	5.8 to 6.0	272 200 200 200	15.00	5.9	5.31	−9.69
Nitrate of soda Acid phosphate Muriate of potash Lime	6	6.0:0	2.6 to 14.0	185 361 131 1,367	14.13	6.6	5.94	−8.19
Sulphate of ammonia Acid phosphate Muriate of potash Lime	2	2.0:0	12.3 to 14.0	180 480 180 1,000	15.90	13.1	11.79	−4.11
Sulphate of ammonia Acid phosphate Sulphate of potash Gypsum	2	2.0:0	6.3 to 7.9	200 200 200 200	14.40	7.1	6.39	−8.01
Sulphate of ammonia Acid phosphate Muriate of potash Gypsum	2	2.0:0	10.2 to 11.3	145 340 100 163	9.73	10.7	9.63	0.10
Sulphate of ammonia Acid phosphate Chlorate of potash Gypsum	1	1.0:0	2.0	168 176 88 100	....	[a] 2.0	[a] 1.80	....
Sulphate of ammonia Rock phosphate Muriate of potash Gypsum	1	1.0:0	11.9	145 255 100 344	9.22	11.9	10.71	1.49
Sulphate of ammonia Floats Muriate of potash Gypsum	1	1.0:0	3.2	145 250 100 344	9.07	3.2	2.88	−6.19
Sulphate of ammonia Basic slag Muriate of potash Gypsum	1	1.0:0	8.5	145 375 100 344	10.39	8.5	7.65	−2.74
Sulphate of ammonia Phosphoral Muriate of potash Gypsum	2	2.0:0	8.7 to 9.8	145 185 100 344	....	[a] 9.2	[a] 8.28	....
Sulphate of potash Muriate of potash Nitrate of potash Sulphate of magnesium Gypsum	1	1.0:0	4.2	100 100 160 200 100	....	[a] 4.2	[a] 3.78	....
Total	534	18.1:1	....	....	11.40	8.9	8.01	−3.39

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[a] Not included in the total averages, as the cost of fertilizers is not given.

Results of fertilizer tests with wheat soils—Continued.

ORGANIC FERTILIZERS SINGLY.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Dried blood	45	1.0:1	− 6.6 to 9.2	262	5.24	0.5	0.45	− 4.79
Tankage	7	6.0:1	− 1.0 to 8.0	443	5.76	3.5	3.15	− 2.61
Fish scrap	1	1.0:0	9.3	404	8.08	9.3	8.37	0.29
Linseed meal	6	6.0:0	1.1 to 9.1	1,266	24.07	4.9	4.41	−19.66
Boneblack	8	8.0:0	0.4 to 6.2	278	3.06	2.3	2.07	− 0.99
Ground bone	37	4.3:1	− 3.9 to 13.5	463	6.01	4.3	3.87	− 2.14
Cotton seed	2	2.0:0	2.8 to 9.9	1,100	8.80	6.3	5.67	− 3.13
Cotton-seed meal	27	1.0:1	− 5.3 to 5.1	300	3.75	0	0	− 3.75
Castor pomace	2	2.0:0	4.2 to 5.7	475	5.46	4.9	4.41	− 1.05
Wheat bran	4	3.0:1	− 3.5 to 7.4	475	....	[a] 2.2	[a] 1.98	....
Straw	9	3.5:1	− 2.0 to 7.2	....	....	[a] 2.5	[a] 2.25	....
Tobacco stems	1	1.0:0	5.7	2,000	15.00	5.7	5.13	− 9.87
Wool waste	2	2.0:0	4.8 to 6.7	2,000	....	[a] 5.7	[a] 5.13	....
Total	151	2.2:1	....	....	6.03	2.2	1.98	− 4.05

ORGANIC FERTILIZERS AND ONE MINERAL.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Used.	Cost.	Bushels.	Dollars.	Average gain per acre.
Dried blood Nitrate of soda	7	2.5:1	− 2.0 to 5.3	47 120	3.93	1.2	1.08	− 2.85
Dried blood Acid phosphate	42	41.0:1	− 4.5 to 11.3	218 298	6.47	5.0	4.50	− 1.97
Dried blood Muriate of potash	43	1.3:1	− 6.0 to 20.8	200 189	8.03	1.2	1.08	− 6.95
Tankage Acid phosphate	10	10.0:0	0.8 to 9.3	100 100	2.00	4.1	3.69	1.69
Tankage Muriate of potash	2	2.0:0	11.1 to 14.3	670 180	12.67	12.7	11.43	− 1.24
Ground bone Nitrate of soda	2	2.0:0	10.4 to 18.3	600 225	13.42	14.3	12.87	− 0.55
Ground bone Muriate of potash	1	1.0:0	1.0	200 200	7.00	1.0	0.90	− 6.10
Ground bone Lime	4	4.0:0	3.6 to 11.3	320 2,000	10.16	6.8	6.12	− 4.04
Ground bone Salt	3	3.0:0	2.8 to 12.0	200 560	4.84	7.1	6.39	1.55
Boneblack Muriate of potash	2	2.0:0	0.2 to 1.9	50 102	2.79	1.0	0.90	− 1.89
Fish scrap Muriate of potash	4	4.0:0	3.0 to 6.5	240 160	8.32	5.2	4.68	− 3.64
Cotton seed Acid phosphate	3	3.0:0	2.9 to 6.5	873 147	8.01	4.4	3.96	− 4.05
Cotton-seed meal Nitrate of soda	2	2.0:0	4.0 to 6.0	127 56	2.98	5.0	4.50	1.52
Cotton-seed meal Acid phosphate	7	6.0:1	− 0.5 to 15.0	290 220	5.15	5.5	4.95	− 0.20
Cotton-seed meal Muriate of potash	1	1.0:0	5.3	320 160	7.52	5.3	4.77	− 2.75
Cotton-seed meal Kainit	1	1.0:0	1.1	300 200	4.95	1.1	0.99	− 3.96
Cotton-seed meal Cotton-seed hull ashes	2	1.0:1	0 to 1.2	200 80	3.86	0.6	0.54	− 3.32
Wheat bran Muriate of potash	12	11.0:1	− 0.6 to 8.1	1,000 70	....	[a] 4.2	[a] 3.78	....
Wheat bran Salt	4	3.0:1	− 0.2 to 6.0	275 560	....	[a] 3.5	[a] 3.15	....

[a] Not included in the total averages, as the cost of fertilizers is not given.

Results of fertilizer tests with wheat soils—Continued.

ORGANIC FERTILIZERS AND ONE MINERAL—Continued.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Guano Gypsum	3	2.0:1	− 0.8 to 2.7	250 344	7.62	0.7	0.63	−6.99
Wool waste Acid phosphate	2	2.0:0	9.1 to 12.1	2,000 350	......	*a* 10.6	*a* 9.54	....
Wool waste Caustic potash	3	3.0:0	3.7 to 11.0	2,000 900	......	*a* 7.1	*a* 6.39	....
Wool waste Coal ashes	1	1.0:0	9.2	2,000	......	*a* 9.2	*a* 8.28	....
Total	161	5.0:1	....	....	5.96	3.7	3.33	−2.63

ORGANIC FERTILIZERS WITH TWO OR MORE MINERALS.

Dried blood Nitrate of soda Acid phosphate	8	8.0:0	1.4 to 17.8	45 120 160	5.04	9.2	8.28	3.24
Dried blood Nitrate of soda Muriate of potash	20	3.0:1	− 2.0 to 22.2	70 128 120	7.25	5.2	4.68	−2.57
Dried blood Acid phosphate Muriate of potash	167	12.9:1	− 4.1 to 18.0	406 280 188	14.22	7.9	7.11	−7.11
Dried blood Acid phosphate Kainit	11	10.0:1	− 1.1 to 31.1	362 294 236	10.73	10.4	9.36	−1.37
Dried blood Ground bone Muriate of potash	36	36.0:0	0.4 to 14.7	230 230 198	11.97	6.1	5.49	−6.48
Tankage Acid phosphate Sulphate of potash	3	0:3	− 4.8 to −1.7	100 200 80	5.10	−3.6	−3.24	−8.34
Tankage Acid phosphate Muriate of potash	6	6.0:0	1.3 to 10.6	217 190 75	5.79	6.7	6.03	0.24
Tankage Muriate of potash Lime	2	2.0:0	7.7 to 8.6	670 160 1,000	15.67	8.1	7.29	−8.38
Linseed meal Acid phosphate Muriate of potash	13	13.0:0	1.1 to 20.7	500 110 90	12.25	8.7	7.83	−4.42
Boneblack Nitrate of soda Muriate of potash	7	7.0:0	1.4 to 17.6	67 261 102	9.49	6.8	6.12	−3.37
Boneblack Sulphate of ammonia Muriate of potash	3	3.0:0	3.6 to 9.2	50 288 102	11.72	6.3	5.67	−5.05
Ground bone Nitrate of soda Muriate of potash	14	6.0:1	− 0.9 to 21.0	180 148 118	8.63	9.9	8.91	0.28
Ground bone Sulphate of ammonia Muriate of potash	5	4.0:1	− 6.5 to 10.0	180 240 200	14.17	5.1	4.59	−9.58
Ground bone Muriate of potash Lime	6	6.0:0	6.9 to 15.0	320 160 2,000	13.68	10.8	9.72	−3.96
Ground bone Wood ashes Salt	2	2.0:0	7.8 to 9.0	200 1,000 560	7.34	8.4	7.56	0.22
Ground bone Salt Sand	2	1.0:1	− 2.0 to 8.7	200 560 8,800	4.84	3.4	3.06	−1.78

a Not included in the total averages, as the cost of fertilizers is not given.

Results of fertilizer tests with wheat soils—Continued.

ORGANIC FERTILIZERS WITH TWO OR MORE MINERALS—Continued.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Cotton-seed meal Acid phosphate Muriate of potash	4	3.0:1	− 2.5 to 4.7	100 100 25	2.50	1.8	1.62	− 0.88
Cotton-seed meal Acid phosphate Kainit	12	3.0:1	− 3.5 to 4.8	154 237 73	4.02	1.2	1.08	− 2.94
Wool waste Acid phosphate Caustic potash	4	4.0:0	8.8 to 9.9	2,000 350 900	......	[a] 9.4	[a] 8.46	....
Wool waste Acid phosphate Coal ashes	1	1.0:0	12.3	2,000 350	......	[a] 12.3	[a] 11.07	....
Wool waste Caustic potash Coal ashes	1	1.0:0	11.0	2,000 900	......	[a] 11.0	[a] 9.90	....
Dried blood Nitrate of soda Acid phosphate Muriate of potash	40	40.0:0	1.0 to 21.5	42 125 158 92	7.12	9.4	8.46	1.34
Dried blood Nitrate of soda Acid phosphate Kainit	1	1.0:0	7.9	184 150 400 400	12.63	7.9	7.11	− 5.52
Dried blood Nitrate of soda Basic slag Muriate of potash	2	2.0:0	11.4 to 14.6	40 120 65 100	6.40	13.0	11.70	5.30
Tankage Fish scrap Acid phosphate Muriate of potash	2	2.0:0	7.1 to 9.0	346 54 320 160	11.33	8.0	7.20	− 4.13
Ground bone Wood ashes Salt Sand	1	1.0:0	2.4	200 200 560 3,520	5.34	2.4	2.16	− 3.18
Cotton-seed meal Nitrate of soda Acid phosphate Muriate of potash	1	1.0:0	12.2	250 375 250 90	16.22	12.2	10.98	− 5.24
Guano Sulphate of ammonia Muriate of potash Gypsum	3	3.0:0	3.2 to 7.7	250 145 100 344	14.32	5.1	4.59	− 9.76
Total	377	12.5:1	....	....	11.33	7.5	6.75	− 4.58
MANURE AND COMPOST.								
Manure	345	12.3:1	− 9.9 to 41.1	22,429	5.60	6.5	5.85	0.25
Cow manure	16	7.0:1	− 0.7 to 18.7	50,144	12.53	5.8	5.22	− 7.31
Cow urine with chaff	3	2.0:1	− 0.8 to 16.5	32,000	....	[a] 10.5	[a] 9.45	....
Hog manure	2	2.0:0	0.8 to 2.6	32,000	8.00	1.7	1.53	− 6.47
Hen manure	2	2.0:0	2.3 to 12.5	10,000	75.00	7.4	[a] 6.66	−68.34
Pea vines	33	33.0:0	3.3 to 21.7	....	....	[a] 12.2	[a] 10.98	....
Horse manure Cow manure	3	3.0:0	4.6 to 7.7	15,333 15,333	7.67	6.1	5.49	− 2.18
Manure Acid phosphate	20	20.0:0	8.9 to 21.6	16,000 320	6.24	14.6	13.14	6.90
Manure Rock phosphate	4	4.0:0	9.7 to 11.9	16,000	......	[a] 10.7	[a] 9.63	....
Manure Floats	20	20.0:0	7.8 to 22.9	16,000 320	5.28	14.5	13.05	7.77
Manure Kainit	20	20.0:0	4.3 to 19.4	16,000 320	5.92	10.9	9.81	3.89

[a] Not included in the total averages, as the cost of fertilizers is not given.

Results of fertilizer tests with wheat soils—Continued.

MANURE AND COMPOST—Continued.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre.		Crop increase per acre.		Average gain per acre.
				Used.	Cost.			
	Acres.	*Ratio.*	*Bushels.*	*Pounds.*	*Dollars.*	*Bushels.*	*Dollars.*	*Dollars.*
Manure Lime	19	19.0:0	2.9 to 16.1	19,578 3,294	14.77	7.8	7.02	−7.75
Manure Gypsum	20	20.0:0	6.0 to 22.7	16,000 320	5.28	12.4	11.16	5.88
Manure Wood ashes	1	1.0:0	14.7	32,000 1,200	11.00	14.7	13.23	2.23
Manure Salt	6	6.0:0	3.1 to 13.7	32,000 560	10.24	7.5	6.75	−3.49
Manure Sand	3	3.0:0	0.7 to 12.0	32,000 8,800	8.00	6.4	5.76	−2.24
Pea vines Acid phosphate	1	1.0:0	11.8	 300	......	[a] 11.8	[a] 10.64	....
Pea vines Kainit	1	0:1	−1.6	 300	......	[a] −1.6	[a] −1.44	....
Pea vines Cotton-seed meal	1	1.0:0	8.6	 300	......	[a] 8.6	[a] 7.74	....
Manure Ground bone Salt	6	6.0:0	1.5 to 9.6	32,000 1,200 3,360	12.84	5.7	5.13	−7.71
Manure Salt Sand	1	1.0:0	5.5	32,000 560 8,800	10.24	5.5	4.95	−5.29
Manure Wood ashes Salt Sand	1	1.0:0	5.0	32,000 1,200 560 8,800	13.24	5.0	4.50	−8.74
Pea vines Cotton-seed meal Acid phosphate Kainit	2	2.0:0	11.2 to 12.4	...... 131 262 56	......	[a] 11.8	[a] 10.62	....
Compost	3	3.0:0	2.5 to 8.4	3,200	0.80	5.4	4.86	4.06
Total	533	16.8:1	....	....	6.67	7.6	6.84	0.17

COMMERCIAL FERTILIZERS.

Kind of fertilizers used.	Number of experiments.	Increase to no increase.	Range of crop increases.	Fertilizers per acre. Used.	Fertilizers per acre. Cost.	Crop increase per acre. Bushels.	Crop increase per acre. Dollars.	Average gain per acre.
Commercial fertilizers	294	2.3:1	−10.3 to 15.9	350	3.50	2.3	2.07	−1.43

[a] Not included in the total averages, as the cost of fertilizers is not given.

The following table gives the actual number of cases in each class of fertilizer used, showing the increase in production and no increase in production, together with the ratio and the average increase in production in bushels per acre of wheat:

Summary.

Treatment.	Number of experiments.	Number of increases.	Number of no increases.	Ratio.	Average crop increase per acre.
					Bushels.
Minerals alone	799	536	263	2.0:1	2.0
Mixture of two minerals	378	318	60	5.3:1	4.6
Mixture of three or more minerals	534	506	28	18.1:1	8.9
Organic fertilizers singly	151	106	45	2.5:1	2.2
Organic fertilizers with one mineral	161	134	27	5.0:1	3.7
Organic fertilizers with two or more minerals	377	348	29	12.5:1	7.5
Manure and minerals, pea vine and compost	533	503	30	16.8:1	7.6
Commercial fertilizers	294	209	85	2.3:1	2.3
Total	3,227	2,660	567	4.7:1	....

It appears from this that the chances to obtain an increase in yield and the actual increase in yield are greater with two or three substances mixed than with a single substance, both in case of the minerals and in case of organic fertilizers to which minerals are added. There is, in fact, in the data evidence tending to prove that the fertilizers have something of an additive value, as the sum of the average increases due to single fertilizers approximates the average increase where the actual mixture has been used. However, in the majority of cases, the mixture gives greater increase than the sum. This will appear in the following table:

Increase in yield of wheat per acre due to single fertilizers compared with increase due to mixtures of these fertilizers.

Fertilizers.	Number of experiments.	Increase per acre.
Nitrate of soda	103	1.7
Acid phosphate	192	3.5
		5.2
Mixture	68	6.7
Nitrate of soda	103	1.7
Muriate of potash	114	0.4
		2.1
Mixture	72	3.6
Acid phosphate	192	3.5
Muriate of potash	114	0.4
		3.9
Mixture	185	4.9
Nitrate of soda	103	1.7
Acid phosphate	192	3.5
Muriate of potash	114	0.4
		5.6
Mixture	295	8.9
Nitrate of soda	103	1.7
Rock phosphate	25	3.6
Muriate of potash	114	0.4
		5.7
Mixture	14	2.6
Nitrate of soda	103	1.7
Basic slag	14	6.5
Muriate of potash	114	0.4
		8.6
Mixture	16	7.7
Sulphate of ammonia	25	3.6
Acid phosphate	192	3.5
Muriate of potash	114	0.4
		7.5
Mixture	158	9.4
Dried blood	45	0.5
Acid phosphate	192	3.5
		4.0
Mixture	42	5.0
Dried blood	45	0.5
Nitrate of soda	103	1.7
Muriate of potash	114	0.4
		2.6
Mixture	20	5.4
Dried blood	45	0.5
Acid phosphate	195	3.5
Muriate of potash	114	0.4
		4.4
Mixture	167	7.5
Dried blood	45	0.5
Acid phosphate	192	3.5
Kainit	21	1.4
		5.4
Mixture	11	10.4
Dried blood	45	0.5
Ground bone	37	4.3
Muriate of potash	114	0.4
		5.2
Mixture	36	6.1
Linseed meal	6	4.9
Acid phosphate	192	3.5
Muriate of potash	114	0.4
		8.8
Mixture	13	8.7
Ground bone	37	4.3
Nitrate of soda	103	1.7
Muriate of potash	114	0.4
		6.4
Mixture	14	9.9
Cotton-seed meal	27	....
Acid phosphate	192	3.5
Kainit	21	1.4
		4.9
Mixture	12	1.2
Dried blood	45	0.5
Nitrate of soda	103	1.7
Acid phosphate	192	3.5
Muriate of potash	114	0.4
		6.1
Mixture	40	9.4

The following table contains all the data available to determine the effect of increasing the amount of fertilizer applied to the soil. All experiments on any soil and in any year when the amount of nitrate of soda applied, for example, is between 75 and 99 pounds per acre are summed up and weighted averages are obtained. The number of experiments is given in each case, with the absolute range of crop increase.

Increase in yield of wheat attributable to different amounts of fertilizers.

Name of fertilizer.	Quantity per acre.	Number of experiments.	Range of crop increase.	Average increase per acre.
	Pounds.		*Bushels.*	*Bushels.*
Nitrate of soda	75 to 99	3	0 to 9.6	4.2
	100 to 149	8	– 2.4 to 4.2	1.3
	150 to 199	59	– 8.3 to 11.6	1.9
	200 to 299	18	– 3.0 to 7.7	2.9
	300 to 399	5	– 9.3 to 8.2	–0.1
	400 to 499	10	–10.3 to 9.2	–1.6
Sulphate of ammonia	40 to 74	2	4.1 to 6.2	5.2
	100 to 149	2	2.7 to 6.7	4.7
	150 to 199	4	– 4.3 to 4.7	2.1
	200 to 299	11	– 1.7 to 8.8	3.2
	300 to 399	4	– 0.6 to 15.1	5.2
	400+	2	0.7 to 4.6	2.6
Acid phosphate	40 to 74	1	0 to 3.0	3.0
	100 to 149	10	– 1.6 to 10.4	2.8
	150 to 199	23	– 5.7 to 18.1	5.3
	200 to 299	28	– 5.0 to 9.0	2.8
	300 to 399	82	– 5.0 to 21.4	3.4
	400 to 499	39	– 4.0 to 16.3	3.4
	500+	9	– 0.1 to 9.2	4.4
Rock phosphate	200 to 299	2	0.8 to 4.1	2.5
	300 to 399	2	– 2.0 to 4.0	1.0
	400 to 499	4	– 6.5 to 2.0	–2.7
	500+	17	– 2.7 to 13.4	5.5
Muriate of potash	40 to 74	9	– 1.5 to 2.8	0.7
	75 to 99	12	0.3 to 6.2	2.2
	100 to 149	25	– 3.8 to 12.5	1.9
	150 to 199	37	– 7.6 to 11.9	–0.5
	200 to 299	30	– 4.0 to 9.0	–0.4
Lime	Below 500	6	– 5.6 to – 0.4	–1.8
	500 to 999	7	– 0.8 to 4.2	2.6
	1,000 to 1,999	29	– 2.8 to 11.7	1.6
	2,000 to 2,999	21	– 3.8 to 16.7	3.4
	3,000 to 3,999	10	1.0 to 11.3	4.9
	4,000+	58	– 3.5 to 12.9	2.0
Gypsum	Below 200	3	– 1.9 to 1.4	0.2
	200 to 299	10	– 4.3 to 2.8	–0.7
	300 to 399	63	–15.9 to 10.1	–0.6
	400 to 499	8	– 6.8 to 4.3	–0.9
	500+	9	– 7.5 to 6.2	–1.3
Dried blood	150 to 199	10	– 6.3 to 3.5	–1.0
	200 to 299	25	– 6.6 to 7.2	–0.04
	300 to 399	4	– 1.9 to 9.2	3.9
	500+	5	– 2.0 to 8.8	3.6
Ground bone	Below 200	2	1.0 to 2.5	1.8
	200 to 399	14	– 3.9 to 12.3	1.8
	400 to 599	5	0.3 to 6.5	2.3
	600 to 799	13	– 1.5 to 13.5	7.7
	800+	3	4.9 to 7.3	6.3
Cotton-seed meal	Below 200	1	0 to 0.3	0.3
	200 to 299	8	– 5.3 to 3.4	–0.1
	300 to 399	13	– 2.7 to 6.2	1.8
	400 to 499	3	– 2.9 to 4.5	0.5
	500+	2	1.0 to 2.8	1.9
Manure	Below 1,000	1	0 to – 2.4	–2.4
	1,000 to 9,999	46	– 1.8 to 13.1	4.9
	10,000 to 14,999	57	0 to 18.7	7.0
	15,000 to 19,999	80	– 9.9 to 15.0	6.6
	20,000 to 29,999	49	– 4.7 to 41.1	8.1
	30,000 to 39,999	62	– 1.5 to 18.6	6.9
	40,000+	50	– 6.9 to 35.1	5.4
Commercial fertilizers	Below 200	35	– 7.1 to 12.3	2.1
	200 to 399	183	–10.3 to 15.0	1.3
	400 to 599	29	– 4.8 to 13.2	2.1
	600 to 999	35	– 1.5 to 15.9	6.5
	1,000+	12	– 0.2 to 12.4	4.9

It would appear from these data that while the results are somewhat irregular there is, on the whole, no indication of any consistent increase in productivity with increasing amounts of fertilizer used.

In order to determine, if possible, whether the effectiveness of the fertilizers is dependent in any marked way upon the productivity of the soil, all the available data have been brought together in the following table. As an example of the use of this table, it will be seen that there are thirteen cases in which nitrate of soda (in varying amounts) has been applied to soils where the check or unfertilized plat has yielded at the same time below 5 bushels of wheat per acre. On these thirteen plats the weighted average increase attributable to nitrate of soda has been 1.8 bushels per acre.

Increase in yield of wheat attributable to fertilizers, arranged in accordance with the actual yield of the check plat.

Fertilizer.	Yield of unfertilized plats.	Number of experiments.	Range of increase.	Average increase.
	Bushels.		*Bushels.*	*Bushels.*
Nitrate of soda	Below 5.0	13	– 0.3 to 7.7	1.8
	5.0 to 9.9	14	– 1.3 to 6.0	2.7
	10.0 to 14.9	19	– 5.0 to 9.2	1.8
	15.0 to 19.9	24	– 8.3 to 6.2	1.5
	20.0 to 24.9	4	0 to 6.8	3.4
	25.0 to 29.9	7	0.3 to 7.3	3.6
	30.0 to 34.9	11	– 9.3 to 11.6	2.3
	35.0 to 39.9	1	–1.7	–1.7
	40.0+	9	–10.3 to 4.6	–4.1
Acid phosphate	Below 5.0	29	– 1.6 to 18.1	4.7
	5.0 to 9.9	34	– 4.3 to 10.7	4.4
	10.0 to 14.9	29	– 1.6 to 21.4	3.9
	15.0 to 19.9	44	– 5.7 to 12.7	3.2
	20.0 to 24.9	25	– 5.0 to 14.7	1.7
	25.0 to 29.9	16	– 6.1 to 8.8	2.2
	30.0 to 34.9	12	– 2.1 to 9.8	4.3
	35.0 to 39.9	4	– 0.5 to 4.3	2.4
	40.0+	5	– 4.0 to 7.2	0.8
Muriate of potash	Below 5.0	20	– 3.4 to 3.2	–0.6
	5.0 to 9.9	19	– 3.8 to 7.4	1.1
	10.0 to 14.9	16	– 5.3 to 4.2	–0.1
	15.0 to 19.9	26	– 4.4 to 12.5	0.8
	20.0 to 24.9	15	– 4.4 to 11.9	0.3
	25.0 to 29.9	5	– 3.3 to 6.2	1.7
	30.0 to 34.9	11	– 7.6 to 5.2	0.4
	35.0 to 39.9	1	9.8	9.8
	40.0+	3	– 4.3 to 4.5	–0.7
Lime	Below 5.0	29	– 2.4 to 16.7	2.4
	5.0 to 9.9	17	– 3.5 to 7.5	1.1
	10.0 to 14.9	32	– 5.6 to 12.9	2.6
	15.0 to 19.9	22	– 1.4 to 5.6	1.7
	20.0 to 24.9	28	– 1.1 to 9.9	3.0
	25.0 to 29.9	3	3.0 to 6.6	4.5
	30.0 to 34.9	2	– 1.1 to 8.5	3.7
	35.0 to 39.9	1	–2.0	–2.0
	40.0+	3	– 6.0 to 0.6	–3.1
Gypsum	Below 5.0	15	– 1.9 to 3.9	0.1
	5.0 to 9.9	9	– 3.4 to 4.3	0.9
	10.0 to 14.9	16	– 6.8 to 6.2	–2.0
	15.0 to 19.9	23	– 4.6 to 6.0	–0.9
	20.0 to 24.9	24	–15.9 to 10.1	–0.8
	25.0 to 29.9	3	– 2.8 to 4.3	1.9
	30.0 to 34.9	2	– 7.5 to 1.8	–4.6
	35.0 to 39.9	2	2.0 to 2.0	2.0
	40.0+	1	–2.3	–2.3

Increase in yield of wheat attributable to fertilizers, arranged in accordance with the actual yield of the check plat—Continued.

Fertilizer.	Yield of unfertilized plats.	Number of experiments.	Range of increase.	Average increase.
	Bushels.		*Bushels.*	*Bushels.*
Nitrate of soda, acid phosphate	Below 5.0	11	0.1 to 11.7	5.6
	5.0 to 9.9	15	− 4.0 to 15.7	8.3
	10.0 to 14.9	12	− 3.6 to 21.8	7.4
	15.0 to 19.9	14	− 2.6 to 15.7	6.4
	20.0 to 24.9	2	14.6 to 16.4	15.5
	25.0 to 29.9	5	2.5 to 7.1	5.0
	30.0 to 34.9	7	− 0.2 to 10.5	5.2
	35.0 to 39.9	0	....	....
	40.0+	2	− 2.2 to 0.7	− 0.8
Nitrate of soda, muriate of potash	Below 5.0	13	− 0.5 to 18.8	3.1
	5.0 to 9.9	12	− 1.6 to 15.1	3.8
	10.0 to 14.9	13	− 3.3 to 8.4	2.0
	15.0 to 19.9	13	1.4 to 9.4	4.7
	20.0 to 24.9	2	6.1 to 15.3	10.7
	25.0 to 29.9	5	2.7 to 16.1	8.0
	30.0 to 34.9	10	− 7.9 to 11.5	3.4
	35.0 to 39.9	1	3.3	3.3
	40.0+	4	− 0.6 to 2.6	0.9
Acid phosphate, muriate of potash	Below 5.0	42	− 0.7 to 20.7	6.3
	5.0 to 9.9	25	1.5 to 14.0	6.8
	10.0 to 14.9	21	− 0.6 to 16.7	7.7
	15.0 to 19.9	43	− 4.3 to 15.8	2.3
	20.0 to 24.9	28	− 3.2 to 13.6	3.0
	25.0 to 29.9	5	− 2.7 to 9.6	4.0
	30.0 to 34.9	7	− 1.9 to 11.2	2.7
	35.0 to 39.9	3	− 1.0 to 9.7	4.4
Nitrate of soda, acid phosphate, muriate of potash	Below 5.0	58	− 0.6 to 16.0	3.9
	5.0 to 9.9	56	1.3 to 25.6	12.3
	10.0 to 14.9	51	− 1.0 to 29.4	9.5
	15.0 to 19.9	72	− 0.9 to 25.5	9.0
	20.0 to 24.9	30	− 1.4 to 16.3	7.5
	25.0 to 29.9	10	1.9 to 10.3	7.0
	30.0 to 34.9	13	− 2.6 to 13.8	5.8
	35.0 to 39.9	1	−0.9	− 0.9
	40.0+	5	− 3.0 to 6.5	3.5
Sulphate of ammonia, acid phosphate, muriate of potash	Below 5.0	27	0.1 to 38.1	12.8
	5.0 to 9.9	21	1.8 to 16.2	11.1
	10.0 to 14.9	19	5.5 to 16.3	11.6
	15.0 to 19.9	40	0.9 to 19.1	8.9
	20.0 to 24.9	27	0.2 to 16.9	7.7
	25.0 to 29.9	14	− 1.0 to 12.6	5.8
	30.0+	9	− 2.5 to 7.1	3.1
Dried blood	Below 5.0	8	− 2.6 to 7.2	0.05
	5.0 to 9.9	3	− 5.6 to −1.9	− 3.2
	10.0 to 14.9	6	− 1.9 to 6.0	1.3
	15.0 to 19.9	11	− 6.3 to 5.0	0.2
	20.0 to 24.9	10	− 6.6 to 3.5	− 0.5
	25.0 to 29.9	0	....	....
	30.0 to 34.9	2	1.2 to 9.0	5.1
	35.0 to 39.9	1	8.8	8.8
	40.0+	3	− 2.0 to 9.2	3.7
Ground bone	Below 5.0	4	7.1 to 12.2	9.9
	5.0 to 9.9	4	− 3.9 to 2.5	− 0.9
	10.0 to 14.9	6	− 2.0 to 7.7	4.4
	15.0 to 19.9	12	− 3.9 to 7.3	1.6
	20.0 to 24.9	9	− 1.3 to 13.5	5.7
	25.0 to 29.9	1	6.4	6.4
	30.0 to 34.9	1	2.4	2.4
	35.0 to 39.9	1	10.9	10.9
	40.0+	1	8.1	8.1
Dried blood, acid phosphate	Below 5.0	11	1.3 to 9.8	4.7
	5.0 to 9.9	4	3.3 to 11.3	7.4
	10.0 to 14.9	5	3.5 to 10.2	7.3
	15.0 to 19.9	10	0.4 to 8.1	4.3
	20.0 to 24.9	11	1.0 to 10.7	4.5
	25.0 to 29.9	1	0.3	0.3
Dried blood, acid phosphate, muriate of potash	Below 5.0	41	− 2.4 to 28.0	8.5
	5.0 to 9.9	17	1.4 to 17.3	12.1
	10.0 to 14.9	27	− 0.2 to 17.6	9.6
	15.0 to 19.9	48	− 4.1 to 16.7	5.7
	20.0 to 24.9	38	− 0.8 to 13.3	6.7
	25.0 to 29.9	1	−2.3	− 2.3
	30.0 to 34.9	1	1.3	1.3
	35.0 to 39.9	2	5.9 to 6.0	5.9

Increase in yield of wheat attributable to fertilizers, arranged in accordance with the actual yield of the check plat—Continued.

Fertilizer.	Yield of unfertilized plats.	Number of experiments.	Range of increase.	Average increase.
	Bushels.		*Bushels.*	*Bushels.*
Manure	Below 5.0	44	0.7 to 16.4	6.6
	5.0 to 9.9	50	– 3.3 to 16.3	8.3
	10.0 to 14.9	84	– 1.3 to 35.0	7.6
	15.0 to 19.9	95	– 6.9 to 18.7	5.6
	20.0 to 24.9	44	– 2.4 to 41.1	7.2
	25.0 to 29.9	16	– 1.0 to 11.7	4.9
	30.0 to 34.9	26	– 4.8 to 18.7	5.8
	35.0 to 39.9	9	– 3.4 to 11.2	2.7
	40.0+	26	– 9.9 to 17.0	3.4
Commercial fertilizers	Below 5.0	5	1.3 to 14.0	4.6
	5.0 to 9.9	38	– 4.6 to 5.6	0.9
	10.0 to 14.9	61	– 4.2 to 15.0	2.0
	15.0 to 19.9	107	– 8.0 to 13.7	2.9
	20.0 to 24.9	4	0.5 to 3.6	2.4
	25.0 to 29.9	28	–10.3 to 7.5	– 0.9
	30.0 to 34.9	28	– 5.9 to 15.9	4.8
	35.0 to 39.9	5	– 7.1 to 14.7	1.7
	40.0+	15	– 4.8 to 12.6	2.9

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While there is considerable irregularity in the results, as would be expected from the great differences in the range of increase, there is no indication of any consistent difference in the increase upon the different classes of soils, using the word "class" in this case to mean soils of like natural productivity, as indicated by the yield of the unfertilized plat.

FERTILIZER PLAT TESTS ON THE SAME SOIL FOR A LONG PERIOD OF YEARS.

It has been pointed out in a preceding page that most of the fertilizer tests on wheat soils have been for single seasons, or at most, continued for only two or three years on the same plat. This leaves open the question of the actual value of the average efficiency and the cumulative effect from year to year, if the fertilization should be carried on for a number of years on the same soil. This question should be answered quite fully by the available records of some of the long-time investigations undertaken in this country and abroad. Those at Rothamsted, England, and at the Ohio and Pennsylvania stations should prove especially instructive. The experiments at the American stations, which have not been under way as long as the Rothamsted work, will be taken up first. Additional light will be thrown on these results when compared with the longer experiments at Rothamsted.

OHIO STATION.

At the Ohio station fertilizer tests have been conducted for fifteen years with wheat in continuous culture and with wheat in a five-year rotation. In the latter case four series of plats were used, thus giving fifteen wheat crops, the same number as with wheat in continuous culture. The other crops in the rotation were corn, oats, and clover and timothy.

In the experiments in continuous wheat culture there are six plats receiving fertilizer treatment, Nos. 2, 3, 5, 6, 8, and 9. The increase per acre, as given in Bulletin 184 and Circulars 83 and 92 of the Ohio Experiment Station, has been platted in figure 1.

The fertilizer treatments have been as follows: Plat 2 (fig. 1) has received 160 pounds of nitrate of soda, 160 pounds of acid phosphate,

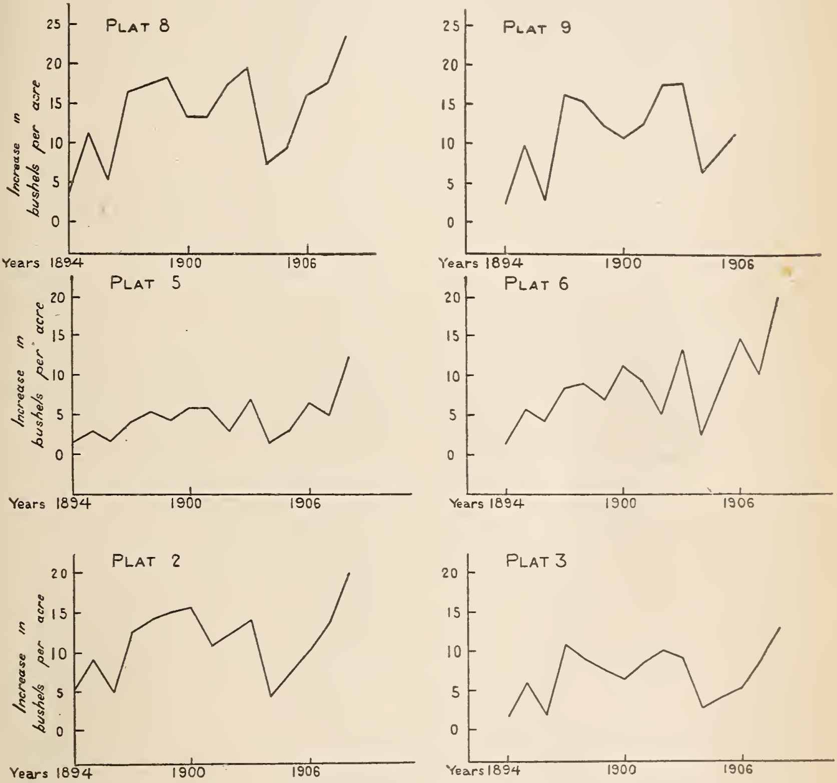

FIG. 1.

and 100 pounds of muriate of potash. Plat 3 has received 160 pounds of nitrate of soda, 60 pounds of acid phosphate, and 30 pounds of muriate of potash. Plat 5 has received 2.5 tons of yard manure. Plat 6 has received 5 tons of yard manure. Plat 8 has received 320 pounds of nitrate of soda, 160 pounds of acid phosphate, and 100 pounds of muriate of potash. Plat 9 has received 320 pounds of nitrate of soda, 120 pounds of acid phosphate, and 60 pounds of muriate of potash. These applications have been made to the soil annually.

The two plats receiving yard manure appear to have increased in productivity within the period of the experiment. On the remainder of the plats receiving only mineral salts the variations are so great and so distributed that it is unsafe to conclude that there has been any progressive or consistent change in the productivity of these plats in the course of the fifteen years.

In the rotation experiments there are 20 plats which have received fertilizer treatment, fertilizers being applied three times in the rotation, namely, to corn, oats, and wheat, except on certain plats where the fertilizer has been omitted with the corn and oats. The differences attributable to the fertilization as given in the experiment station bulletin and circulars, as above mentioned, are platted in figures 2 to 6.

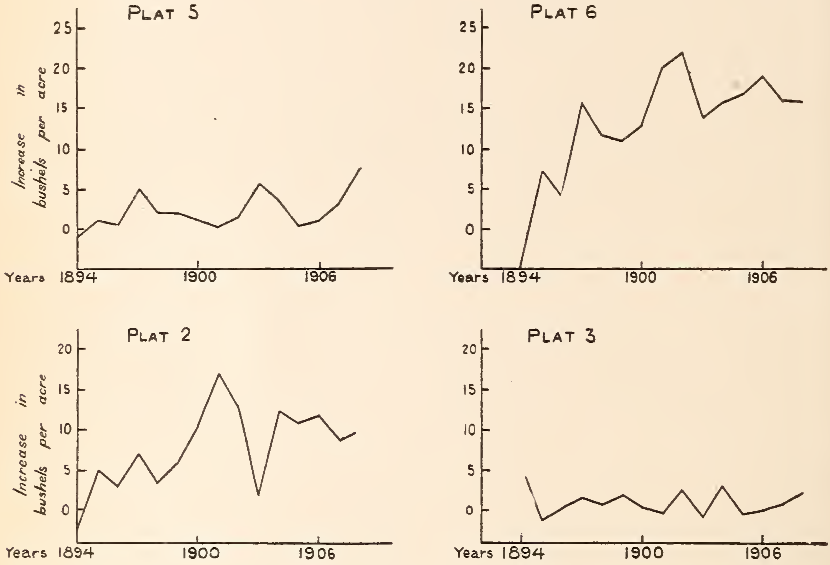

FIG. 2.

Plat 2 (fig. 2) has received annually 160 pounds of acid phosphate; plat 3, 100 pounds of muriate of potash; plat 5, 50 pounds of dried blood and 120 pounds of nitrate of soda; plat 6, 50 pounds of dried blood, 120 pounds nitrate of soda, and 160 pounds of acid phosphate.

Plat 8 (fig. 3) has received annually 160 pounds of acid phosphate and 100 pounds of muriate of potash; plat 9, 50 pounds of dried blood, 120 pounds of nitrate of soda, and 100 pounds of muriate of potash; plat 11, 50 pounds of dried blood, 120 pounds of nitrate of soda, 160 pounds of acid phosphate, and 100 pounds of muriate of potash; plat 12, 50 pounds of dried blood, 200 pounds of nitrate of soda, 160 pounds of acid phosphate, and 100 pounds of muriate of potash.

Plat 14 (fig. 4) has received annually 50 pounds of dried blood, 120 pounds of nitrate of soda, 160 pounds of acid phosphate, and 100 pounds of muriate of potash; plat 15, 50 pounds of dried blood, 120 pounds of nitrate of soda, 160 pounds of acid phosphate, and

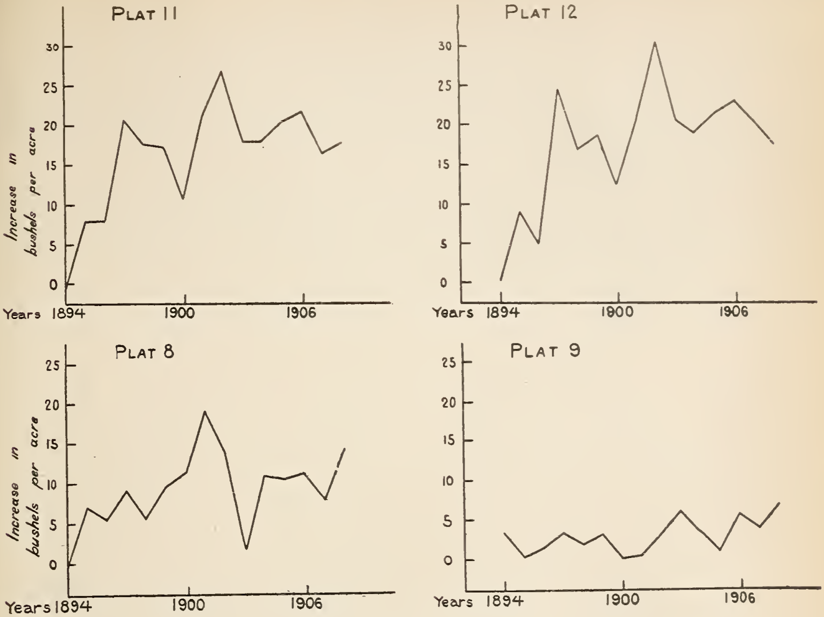

Fig. 3.

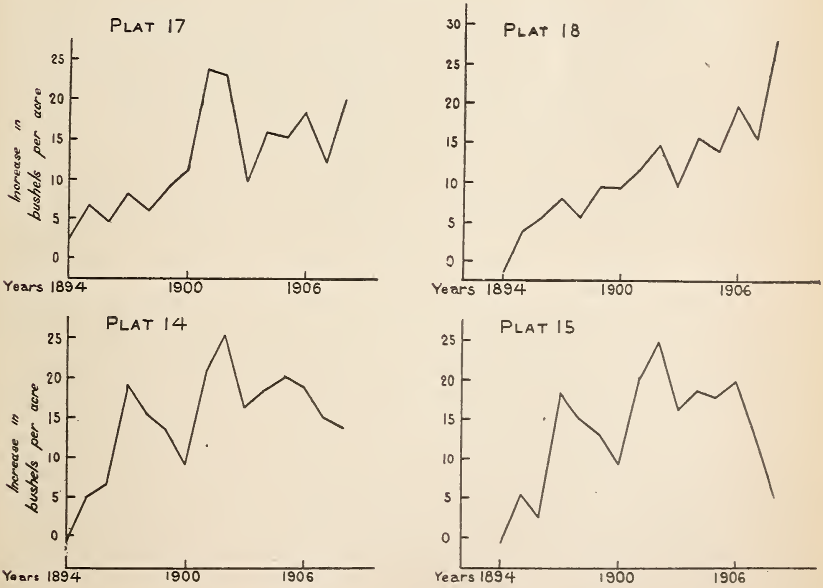

Fig. 4.

100 pounds of muriate of potash; plat 17, 25 pounds of dried blood, 60 pounds of nitrate of soda, 160 pounds of acid phosphate, and 100 pounds of muriate of potash; plat 18, 8 tons of barnyard manure.

Plat 20 (fig. 5) has received annually 4 tons of barnyard manure; plat 21 has had the same elements as plat 17, but nitrogen in oil meal; plat 23 has had the same elements as plat 17, but nitrogen in dried blood; plat 24 has had the same elements as 17, but nitrogen in sulphate of ammonia.

Plat 26 (fig. 6) has had annually the same elements as plat 11, but phosphorus in bone meal; plat 27 has had the same elements as plat 11, but phosphorus in dissolved boneblack; plat 29 has had the same elements as plat 11, but phosphorus in basic slag; and plat 30 has had the same elements as plat 17, but nitrogen in tankage.

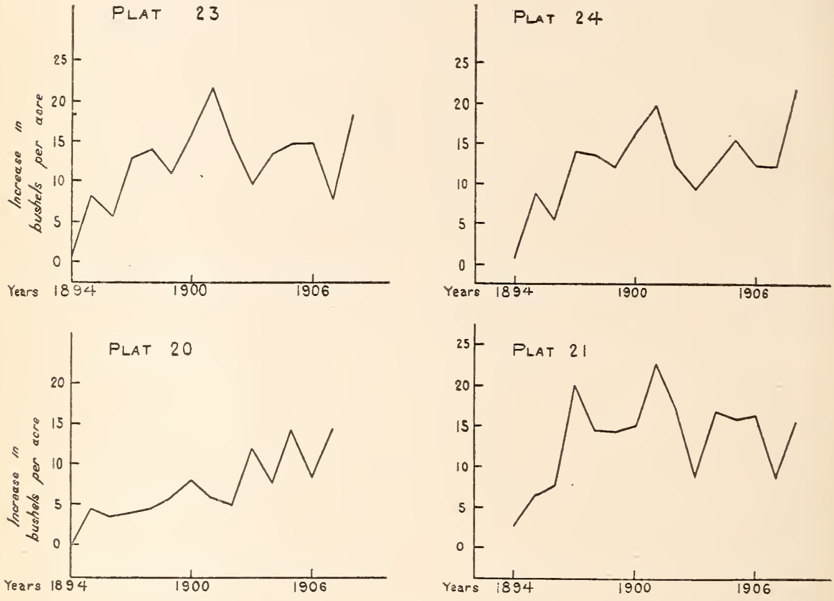

FIG. 5.

It is apparent from the diagrams that the variation in the increases, which may be taken to indicate the effectiveness of the fertilizer, is about as great in the fifteen-year record on the same soil as is shown by the records of the tests which have been made in the United States generally. This extreme variability of plat tests has made it exceedingly difficult to draw conclusions as to the fertilizer requirements of any particular soil and has raised a question as to the length of time required for repeated tests to give reliable information as to the specific fertilizer requirements of a soil.

PENNSYLVANIA STATION.

In the fertilizer experiments carried on at the Pennsylvania State College we have continuous records for twenty-five years;[a] that is, for ten years longer than the Ohio experiments just referred to. Wheat has been grown in rotation with corn, oats, and hay, there being four sets of plats, and fertilizer has been applied twice in the rotation, namely, to corn and to wheat. In the fertilizer plan[b] the actual amount of fertilizing material is not given, but the quantity of fertilizing ingredients is shown.

Plat 2 (fig. 7) has received 24 pounds of nitrogen in the form of dried blood; plat 3, 48 pounds of phosphoric acid in dissolved boneblack; plat 4, 100 pounds of potash in the form of muriate of potash; plat 5, 24 pounds of nitrogen in the form of dried blood, and 48 pounds of phosphoric acid in the form of dissolved boneblack; plat 6 has received dried blood and muriate of potash; plat 7, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash.

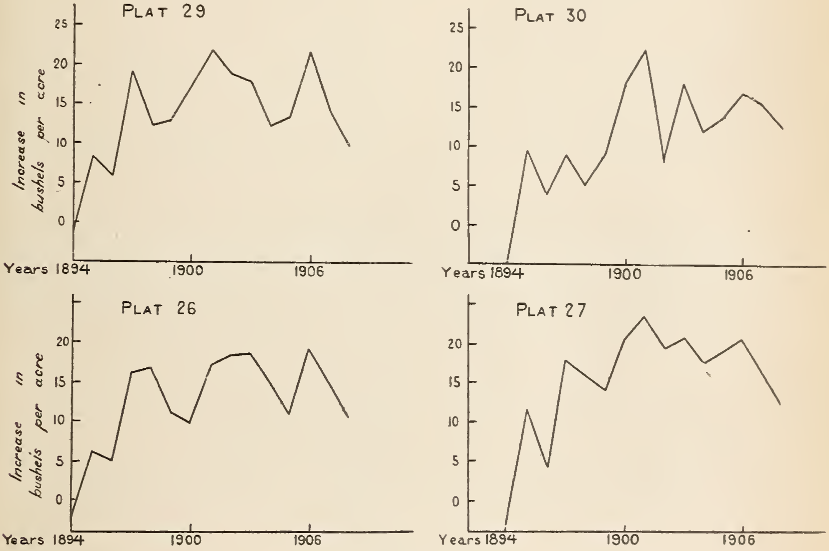

FIG. 6.

Plat 9 (fig. 8) has received 24 pounds of nitrogen in the form of dried blood, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 10, 48 pounds of nitrogen in the form of dried blood, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 11, 72 pounds of nitrogen in the form of dried blood, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 12, 30 pounds of nitrogen, 48 pounds of phosphoric acid, and 100 pounds of potash in dried blood, ground bone, and muriate of potash; plat 13 has received plaster, the amount of which is not given; plat 15, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash.

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[a] Annual Report of the Pennsylvania State College, 1901–2 and 1907–8.

[b] Annual Report of the Pennsylvania State College for the year 1907–8, Part 2, p. 71.

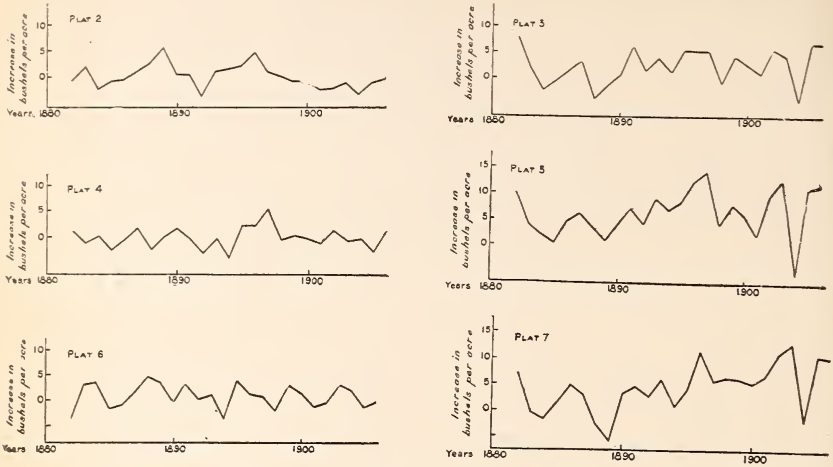

FIG. 7.

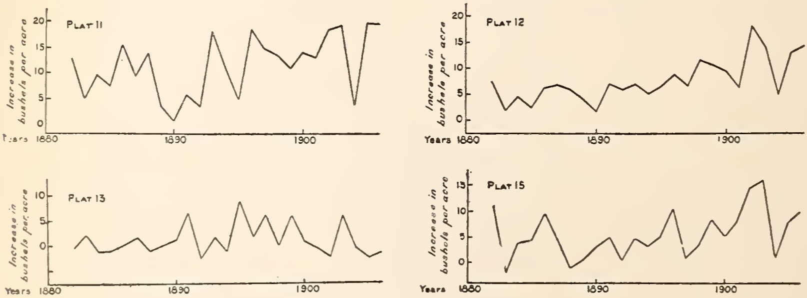

FIG. 8.

Plat 16 (fig. 9) has received an estimated amount of 59 pounds of nitrogen, 38 pounds of phosphoric acid, and 52 pounds of potash in yard manure; plat 17, 24 pounds of nitrogen in the form of dried blood, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 18 has received, as estimated, 78 pounds of nitrogen, 51 pounds of phosphoric acid, and 69 pounds of potash in yard manure; plat 19, 48 pounds of nitrogen in the form of dried blood, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 20 has received, as estimated, 98 pounds of nitrogen, 64 pounds of phosphoric acid, and 86 pounds of potash in yard manure; plat 21, 72 pounds of nitrogen in the form of dried blood, 49 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash.

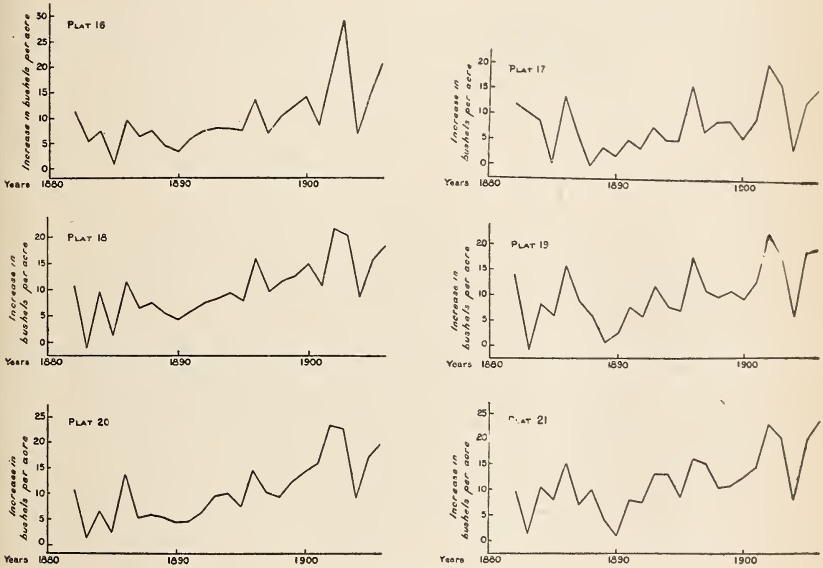

Fig. 9.

Plat 22 (fig. 10) has received, as estimated, 59 pounds of nitrogen, 38 pounds of phosphoric acid, and 52 pounds of potash in yard manure, and lime; plat 23 has received lime, the amount of which is not stated; plat 25, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 26, 24 pounds of nitrogen in the form of nitrate of soda, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 27, 48 pounds of nitrogen in the form of nitrate of soda, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 28, 72 pounds of nitrogen in the form of nitrate of soda, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash.

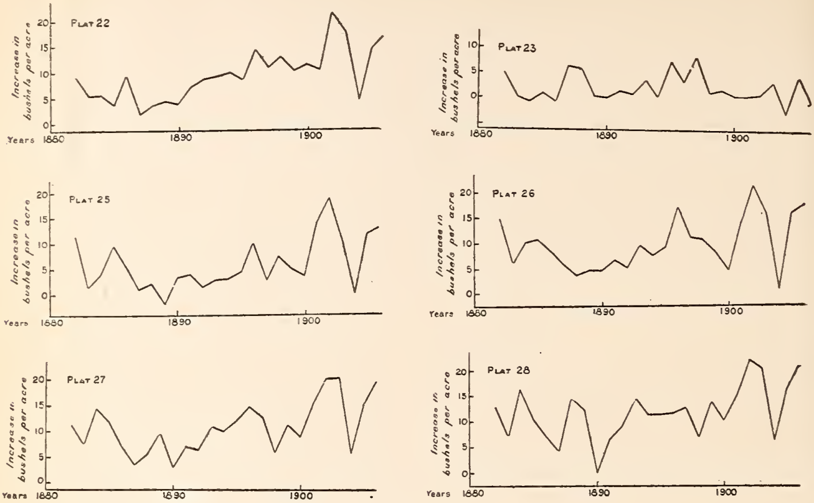

FIG. 10.

Plat 29 (fig. 11) has received 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 30 has received 24 pounds of nitrogen in the form of sulphate of ammonia, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the

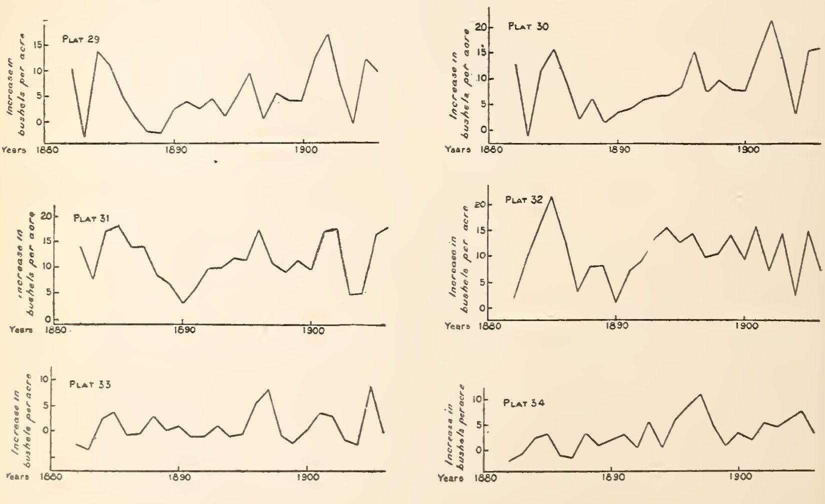

FIG. 11.

form of muriate of potash; plat 31, 48 pounds of nitrogen in the form of sulphate of ammonia, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 32, 72 pounds of nitrogen in the form of sulphate of ammonia, 48 pounds of phosphoric acid in the form of dissolved boneblack, and 100 pounds of potash in the form of muriate of potash; plat 33 has received plaster, the amount of which is not stated; plat 34 has received ground limestone, the amount of which is not stated.

Plat 35 (fig. 12) has received 30 pounds of nitrogen, 48 pounds of phosphoric acid, and 100 pounds of potash, in dried blood, ground bone, and muriate of potash.

In discussing these data the Director of the Pennsylvania Experiment Station says:

> No attempt will be made in this article to discuss the data at length, but only to point out some of the most salient facts that have developed from twenty-five years or experimentation * * *. With this fact before us it is not wise to attempt too wide or too positive generalizations from the results of twenty-five years of field experiments.[a]

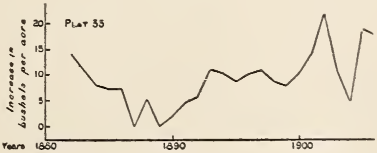

FIG. 12.

Looking at the increases only, as platted in the diagrams, it is unsafe to conclude that there has been any notable change in the efficiency of the fertilizers over the period of twenty-five years, and it must be concluded that with the wide variations from year to year the period is too short to draw positive conclusions.

ROTHAMSTED STATION, BROADBALK FIELD.

The only work to which we can turn for a longer series of experiments than those just reported is that of the English station at Rothamsted. There, on the Broadbalk field, tests with wheat under continuous culture have been carried on for sixty-five years, and on Agdell field with wheat in rotation for approximately the same length of time. The results of these experiments will be briefly stated to aid in the interpretation of the American experiments which have been summarized in the first part of this bulletin. The period covered by the Rothamsted investigations is from 1844 to 1908, inclusive.

In the experiments on the continuous culture of wheat on the Broadbalk field there are recorded the results of 1,746 tests of substances applied to the soil. In working out the data which is presented in the following diagrams the comparison was made between each fertilized plat separately and the average yield of such plats as were unfertilized during that particular year. During this period of sixty-five years the yields of the check plats have varied considerably. In two years the yield of the unfertilized plats averaged less than 5 bushels of wheat per acre.[a]

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[a] Annual Report of the Pennsylvania State College for the year 1907–8, part 2.

There were ten years when the yield of the unfertilized plats averaged between 5 and 10 bushels per acre. There were twenty-seven years when the yield of the unfertilized plats averaged between 10 and 15 bushels per acre. There were twenty years when the yield of the unfertilized plats averaged between 15 and 20 bushels per acre, and six years when the yield of the unfertilized plats averaged more than 20 bushels per acre.

The following table shows the number of fertilizer tests made in the years when the yield of the unfertilized plats fell within these limits of production and the average crop increase from all fertilizer treatments during those years.

Number of fertilizer tests in years of definite yields on check plats.

Yield of check plats (bushels).	Number of fertilizer tests.	Crop increase attributable to all fertilizers.
		Bushels.
Below 5	49	9.3
5 to 10	242	12.2
10 to 15	759	12.5
15 to 20	528	14.0
20 to 25	168	13.4
Total	1,746	

It would appear from this general average that the effectiveness of fertilizers as indicated by the actual increase in crop has been less affected by the season (which has greatly influenced the actual yield on all plats) than is popularly supposed to be the case.

In the following diagrams are platted the actual crop increases attributable to fertilizer applications on each plat where the treatment has been essentially the same in kind and in amount of fertilizers applied for periods exceeding fifteen years, the essential features of the fertilizer treatments for each plat so treated being given in sufficient detail to permit of an intelligent comparison of the diagrams, and the reader is referred to the publications of the Rothamsted station for any additional information which may be desired.

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[a] During most of the period the produce is given in bushels of "dressed corn," and in pounds of "offal corn" per acre. In the summary which is about to be given only the "dressed corn" is considered.

The point to be considered here is not the relative efficiency of the different fertilizers on the soil, which has been quite fully discussed in the various publications of the Rothamsted station, but the direction or path of the increases attributable to each fertilizer during the period of its application.

In 1845 plat 10 (fig. 13) received 168 pounds of sulphate of ammonia and 168 pounds of muriate of ammonia. In 1847 and 1848 plat 10*a* received 150 pounds of sulphate of ammonia and 150 pounds of muriate of ammonia per acre. In 1849 plat 10*a* received 200 pounds of sulphate of ammonia and 200 pounds of muriate of ammonia per acre, and this was continued annually up to and including 1898. In 1847 plat 10*b* received 150 pounds of sulphate of ammonia and 150 pounds of muriate of ammonia per acre. In 1849 and 1851 this plat received 200 pounds of sulphate of ammonia and 200 pounds of muriate of ammonia per acre, and this treatment was continued annually up to and including 1898. In 1899 the treatment was continued on the combined plat 10*a* and 10*b*, and in 1903 it was still continued on plat 10 up to and including 1908.

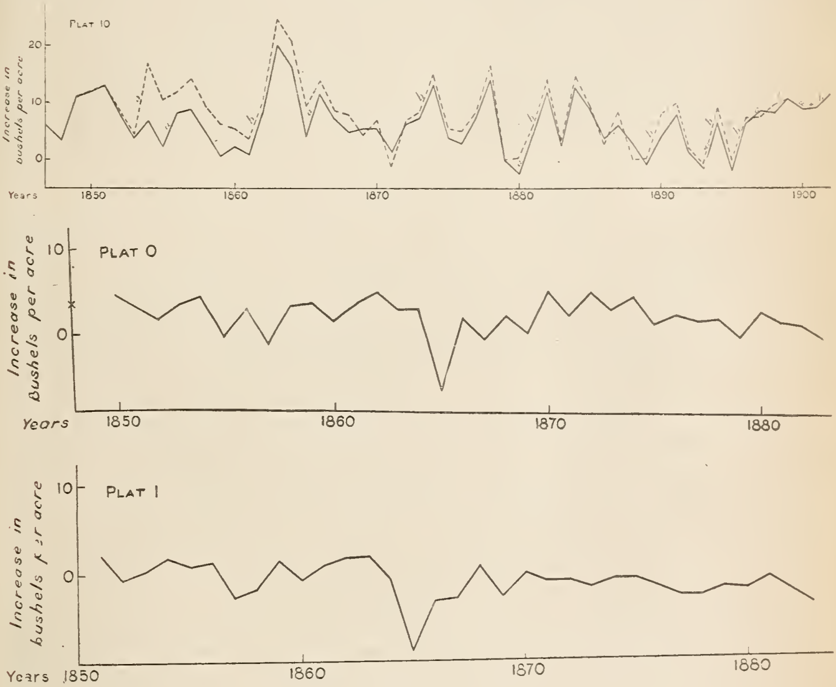

Fig. 13.

In 1848 plat O received an application of 2,240 pounds of superphosphate of lime. In 1850 and annually thereafter this was changed to 600 pounds of bone ash and 450 pounds of sulphuric acid per acre.

Plat 1 at first received annually 600 pounds of sulphate of potash, 400 pounds of sulphate of soda, and 200 pounds of sulphate of magnesia per acre. In 1859 and annually thereafter the amounts were reduced, respectively, to 400, 200, and 200 pounds per acre.

In 1847 plat 11*a* (fig. 14) received at the rate of 150 pounds of sulphate of ammonia, 150 pounds of muriate of ammonia, 100 pounds of bone ash, and 100 pounds of sulphuric acid per acre. In 1849 the amounts were changed to 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, and 150 pounds of sulphuric acid per acre, and this treatment was continued annually up to and including 1883. Plat 11*b* in 1846 received at the rate of 112 pounds of sulphate of ammonia, 112 pounds of muriate of ammonia, 224 pounds of bone ash, and 224 pounds of sulphuric acid per acre. In 1847 the amounts were changed to 150 pounds of sulphate of ammonia, 150 pounds of muriate of ammonia, 100 pounds of bone ash, and 100 pounds of sulphuric acid per acre. In 1848 the amounts were again changed to 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, and 150 pounds of sulphuric acid per acre. This treatment was continued annually up to and including 1883. In 1884 plats 11*a* and 11*b* received annually 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, and 492 pounds of superphosphate of lime per acre. This treatment was continued up to and including 1898, and was continued on plat 11 annually from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases for these four years have been omitted from the diagram.

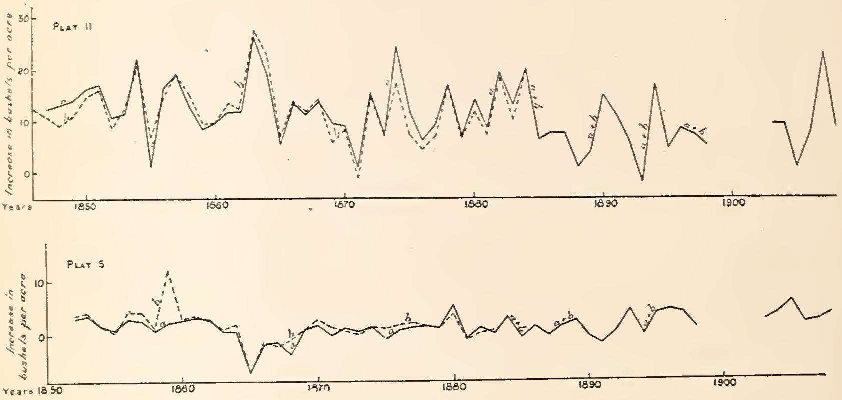

Fig. 14.

From 1852 plats 5*a* and 5*b* received annually fertilizers at the rate of 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre until 1859, in which year the potash and soda salts were reduced, respectively, to 200 and 100 pounds per acre. This treatment was continued annually up to and including 1883. In 1884 on the combined plats *5a* and *5b* the bone ash and sulphuric acid were replaced by 492 pounds of superphosphate of lime. This was continued up to and including 1898, and on plat 5 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases for these four years are omitted from the diagram.

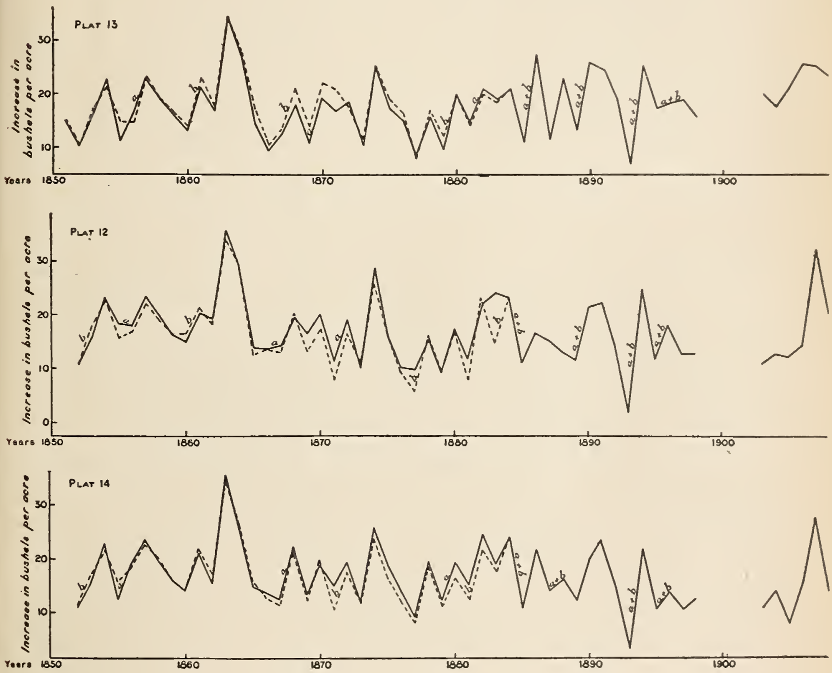

FIG. 15.

In 1851 and annually thereafter plats 13*a* and 13*b* (fig. 15) were fertilized at the rate of 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, and 150 pounds of sulphuric acid, and 300 pounds of sulphate of potash per acre. In 1859 the sulphate of potash was reduced to 200 pounds and the treatment continued up to and including 1883. In 1884 the plats were combined into 13*a* and 13*b*, and 492 pounds of superphosphate of lime was substituted for the bone ash and sulphuric acid. This treatment was continued annually up to and including 1898, and was continued on plat 13 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases for these four years have been omitted from the diagram.

In 1852 plats 12*a* and 12*b* received at the rate of 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, and 550 pounds of sulphate of soda per acre. This treatment was continued annually until 1859, in which year the amount of sulphate of soda was reduced to 366½ pounds per acre, after which the treatment was continued up to and including 1883. In 1884 the plats were combined as 12*a* and 12*b* and received 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 492 pounds of superphosphate of lime, 366½ pounds of sulphate of soda per acre. This treatment was continued up to and including 1898, and was continued on plat 12 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases during these four years have been omitted from the diagram.

In 1852 plats 14*a* and 14*b* each received at the rate of 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, and 420 pounds of sulphate of magnesia per acre, and this treatment was continued annually until 1859, in which year the sulphate of magnesia was decreased to 280 pounds per acre. This treatment was then continued up to and including 1883. In 1884 the combined plats 14*a* and 14*b* had 492 pounds of superphosphate of lime substituted for the bone ash and sulphuric acid, and this treatment was continued up to and including 1898, and was continued on plat 14 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases for these years are omitted from the diagram.

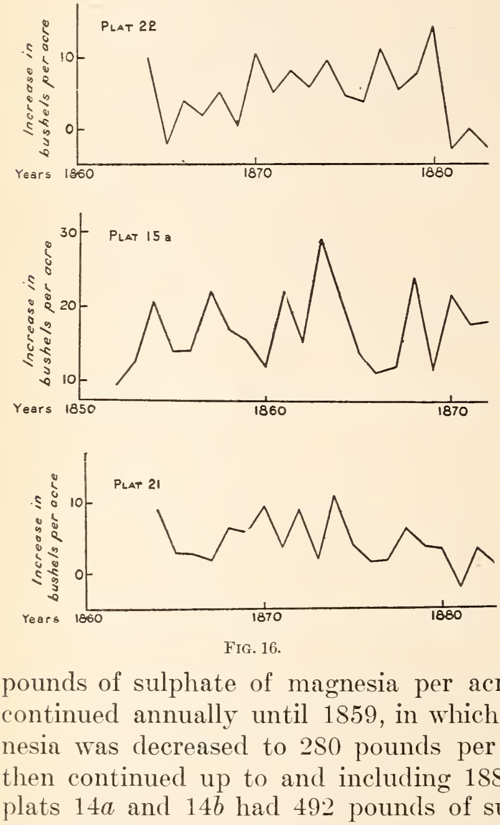

FIG. 16.

From 1864 to 1883, inclusive, plat 22 (fig. 16) received annually at the rate of 100 pounds of sulphate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre.

In 1852 and annually thereafter plat 15*a* received 400 pounds of sulphate of ammonia, 200 pounds of bone ash, 200 pounds of muriatic acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia until 1859, in which year and up to and including 1872 the amounts of potash and soda salts were reduced to 200 and 100 pounds per acre, respectively.

In 1864 and annually thereafter plat 21 received at the rate of 100 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre.

From 1852 plats 6*a* and 6*b* (fig. 17) each received annually at the rate of 100 pounds of sulphate of ammonia, 100 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre until 1859, in which year the amounts of potash and soda salts were reduced to 200 and 100 pounds per acre, respectively. This treatment was continued annually up to and including 1883. In 1884 the plats were combined into plats 6*a* and 6*b* and the bone ash and sulphuric acid were replaced with 492 pounds of superphosphate of lime, which treatment was continued up to and including 1898 and was continued on plat 6 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases for these four years have been omitted from the diagram.

From 1852 plats 7*a* and 7*b* received annually at the rate of 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia until 1859, in which year the amount of potash and soda salts was reduced to 200 and 100 pounds per acre, respectively, up to and including 1883. In 1884, under plats 7*a* and 7*b* the bone ash and sulphuric acid were replaced with 492 pounds of superphosphate of lime up to and including 1898, and this treatment was continued on plat 7 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was introduced in place of the superphosphate of lime, and the crop increases for these four years have been omitted from the diagram.

Plats 15*a* and 15*b*, from 1873 to 1883, inclusive, each received annually 200 pounds of sulphate of ammonia, 200 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia. From 1884 to 1894, inclusive, the bone ash and sulphuric acid were replaced with 492 pounds of superphosphate or lime, and this treatment was continued on plats 15*a* and 15*b* from 1895 to 1898, inclusive, and on plat 15 from 1903 to 1908, inclusive. In the four years from 1899 to 1902, inclusive, 400 pounds of basic slag was substituted for the superphosphate of lime, and the crop increases for these four years are omitted from the chart.

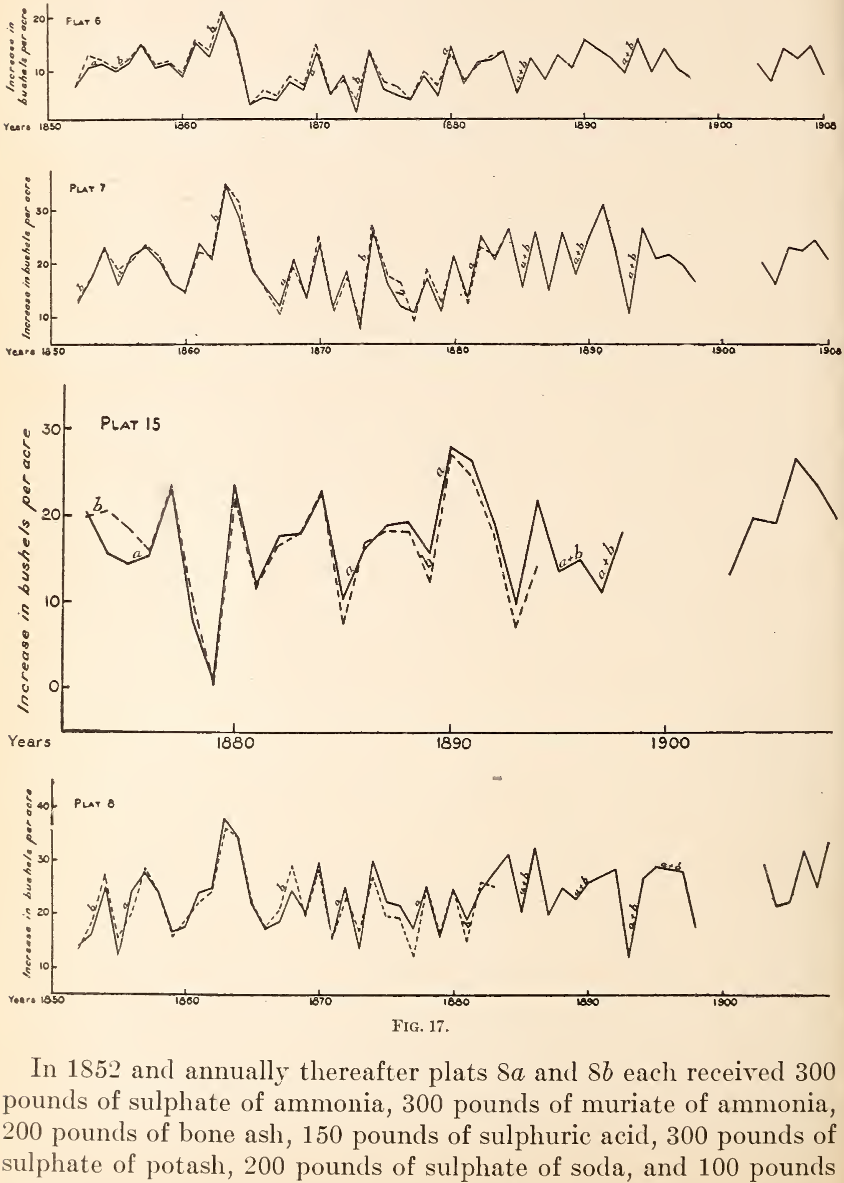

Fig. 17.

In 1852 and annually thereafter plats 8*a* and 8*b* each received 300 pounds of sulphate of ammonia, 300 pounds of muriate of ammonia, 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia until 1859, in which year and up to and including 1883 the sulphate of potash was reduced to 200 pounds and the sulphate of soda was reduced to 100 pounds per acre. In 1884 these plats were combined and the bone ash and sulphuric acid were replaced with 492 pounds of superphosphate of lime, which treatment was continued up to and including 1898, and from 1903 to 1908, when the plats were regarded simply as plat 8. In the four years from 1899 to 1902, inclusive, 400 pounds of basic slag was substituted for the superphosphate of lime, and the crop increases for these four years are omitted from the diagram.

From 1852 to 1908, inclusive, in every alternate, even year, plats 17*a* and 17*b* (fig. 18) received at the rate of 200 pounds per acre of sulphate of ammonia and 200 pounds of muriate of ammonia. In 1853, 1855, 1857, and 1859 plats 17*a* and 17*b* received at the rate of 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia. From 1861 to 1883, inclusive, the potash and soda salts were reduced to 200 and 100 pounds, respectively. From 1885 to 1897, inclusive, in each alternate (odd) year the bone ash and sulphuric acid were replaced with 492 pounds of superphosphate of lime, and this was continued on plat 17 during 1903, 1905, and 1907. In 1899 and 1901 the superphosphate of lime was replaced with basic slag, and the crop increases for these years are omitted from the diagram.

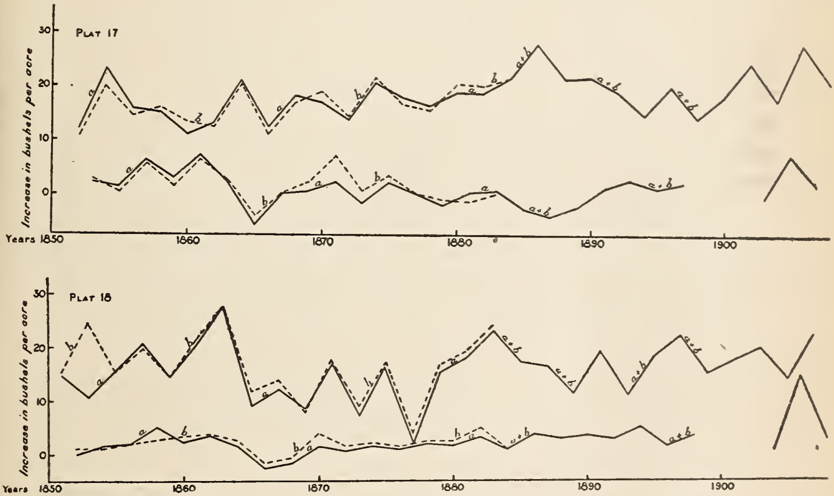

FIG. 18.

The treatment of plats 18*a* and 18*b* alternated likewise from year to year. In 1852, 1854, 1856, and 1858 they each received 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia. From 1860 to 1882, inclusive, in each even year, they received the same treatment, except that the amounts of potash and soda salts were 200 and 100 pounds per acre, respectively. From 1884 to 1898, inclusive, plats 18*a* and 18*b* received in each even year 492 pounds of superphosphate of lime, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia, and this treatment was continued on plat 18 in 1904, 1906, and 1908. In 1900 and 1902 this plat received basic slag instead of superphosphate of lime, and the crop increases for these years are omitted from the chart. From 1851 to 1883, inclusive, in each odd year, plats 18*a* and 18*b* each received 200 pounds of sulphate of ammonia and 200 pounds of muriate of ammonia per acre. From 1885 to 1899, inclusive, plats 18*a* and 18*b* received in every alternate (odd) year 200 pounds of sulphate of ammonia and 200 pounds of muriate of ammonia, and this treatment was continued on plat 18 in alternate years from 1901 to 1907, inclusive.

One interesting point brought out in the diagrams in figure 18 is that in addition to the direction of the path of each fertilizer on each plat is the notable difference in the path of efficiency of each fertilizer when applied in alternate years. The mean path of the phosphate and sulphates lies not far from the line of zero efficiency, notwithstanding the fact that the mean path of efficiency of the ammonia salts applied in the alternate years is some 15 bushels above the zero point.

In 1852 plat 9*b* (fig. 19) received 475 pounds of nitrate of soda. In 1853 this was increased to 550 pounds and applied annually until 1883, after which the amount was reduced to 275 pounds per acre for the remainder of the period.

In 1855 plat 9*a* received at the rate of 550 pounds of nitrate of soda, 200 pounds of bone ash, 150 pounds of sulphuric acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre. This treatment was continued annually up to 1859, in which year the potash and soda salts were reduced to 200 and 100 pounds per acre, respectively. This treatment was then continued up to and including 1883. In 1884 the plat received at the rate of 275 pounds of nitrate of soda, 492 pounds of superphosphate of lime, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia, and this treatment was continued annually up to and including 1898, and was continued on plat 9 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime, and the crop increases during these four years are omitted from the diagram.

In 1894 plat 9*b* received at the rate of 275 pounds of nitrate of soda, 492 pounds of superphosphate of lime, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre, and this treatment was continued annually up to and including 1898.

In 1884 plat 16 received at the rate of 550 pounds of nitrate of soda, 492 pounds of superphosphate of lime, 200 pounds of sulphate of potash, 100 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre. This treatment was continued up to and including 1898, and was continued on plat 16 from 1903 to 1908, inclusive. During the four years from 1899 to 1902, inclusive, basic slag was substituted for the superphosphate of lime and the crop increases during these four years have been omitted from the diagram.

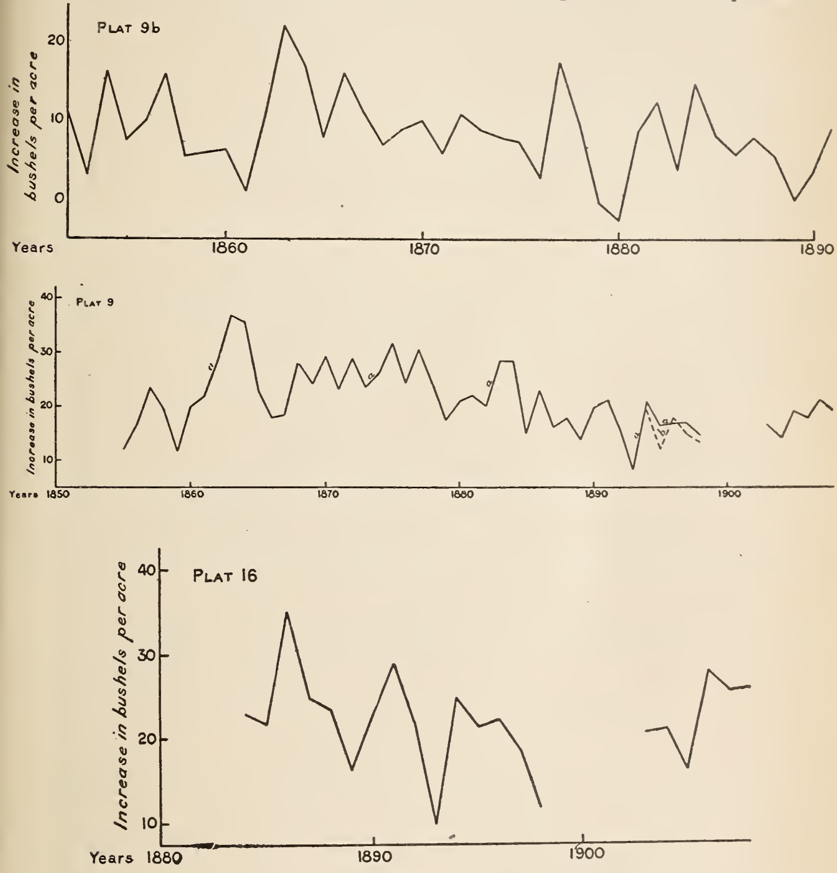

FIG. 19.

In 1879 plat 19 (fig. 20) received at the rate of 1,700 pounds of rape cake per acre annually until 1883, in which year the amount was increased to 1,889 pounds per acre, which amount was applied annually thereafter up to and including 1908.

In 1845 plat 19 received at the rate of 336 pounds of rape cake, 112 pounds of sulphate of ammonia, 112 pounds of bone ash, and 112 pounds of muriatic acid per acre. In 1848 it received at the rate of 500 pounds of rape cake, 300 pounds of sulphate of ammonia, 200 pounds of bone ash, and 200 pounds of muriatic acid per acre, and this treatment was continued annually up to and including 1878.

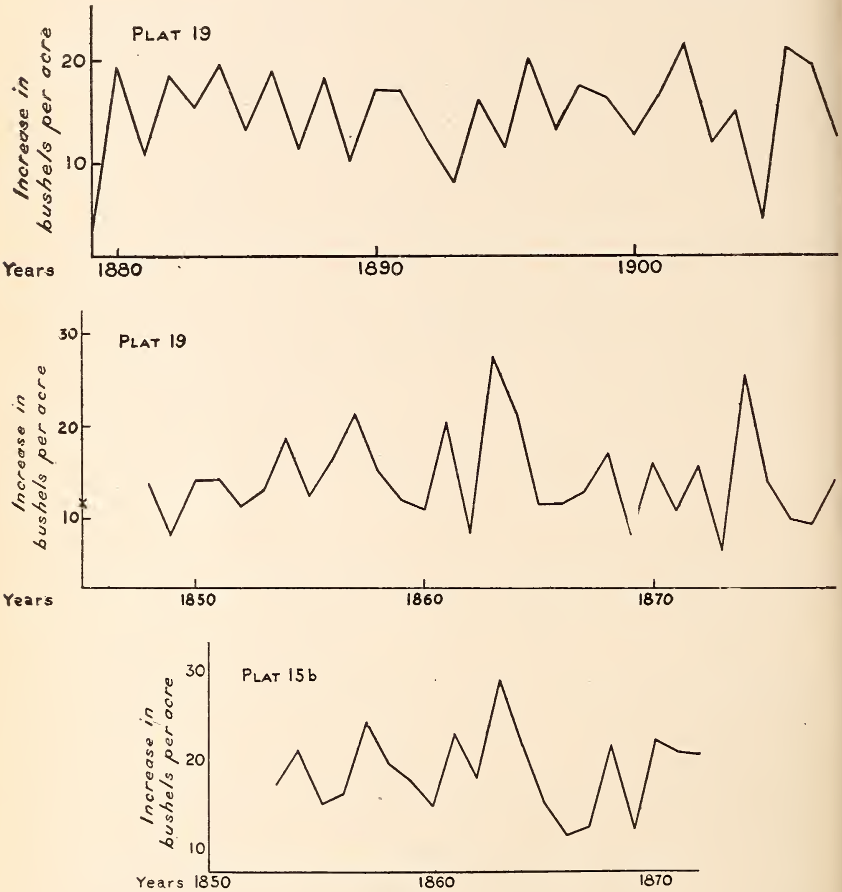

FIG. 20.

In 1853 plat 15*b* received at the rate of 500 pounds of rape cake, 300 pounds of sulphate of ammonia, 200 pounds of bone ash, 200 pounds of muriatic acid, 300 pounds of sulphate of potash, 200 pounds of sulphate of soda, and 100 pounds of sulphate of magnesia per acre. This treatment was continued annually until 1859, in which year the potash and soda salts were reduced to 200 and 100 pounds per acre, respectively, and so remained up to and including 1872.

Plat 2 (fig. 21) received 31,360 pounds of stable manure annually throughout the period.

With the exception of plat 2, receiving stable manure, one is unable to say with any degree of certainty that any of the fertilizers show an increasing efficiency with increasing years of use. One is forced to conclude that the rather wide seasonal variations of fertilizer efficiency are contained in a path the mean direction of which is practically horizontal. Furthermore, as the variations in fertilizer efficiency on the same soil in these long-time experiments are at least of the same order of magnitude as the range of efficiency in the American results, it would appear that the unknown factors which cause this variation of efficiency are sufficiently great to mask soil type influences from one and the same fertilizers and that, so far as plat experiments can be relied upon as guides for fertilizer practice, the American results, where a sufficient number of tests have been made, are as reliable in judging of the relative efficiency of different fertilizer materials as if they had been conducted upon the same soil as in the English experiments. The fundamental problem remaining to be investigated is the cause of the variations in efficiency of fertilizers to the end that they may be applied with greater certainty of result and consequent greater financial return.

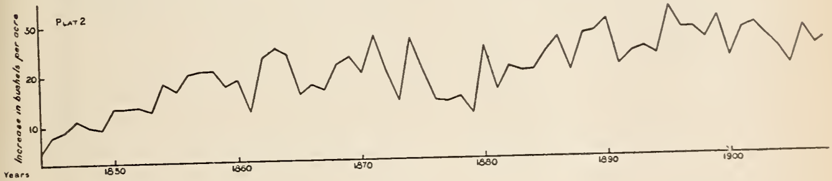

FIG. 21.

ROTHAMSTED STATION AGDELL FIELD.

There is another series of experiments which have been carried on since 1851 on the Rothamsted farm which should have a bearing upon the interpretation of the American results summarized in this bulletin. This is the rotation experiment on the Agdell field, the results of which are given in figures 22 to 28. In this experiment there have been two plats, Nos. 2 and 3, repeated four times with slightly different treatments. The rotation has been turnips, barley, leguminous crop (or fallow), and wheat. The fertilizers have been added only to the turnip crop, three years before the wheat crop occupied the land. Plat 2 has had superphosphate of lime alone in the first nine courses and a complex mineral manure from course 10 onward. The composition of this mineral manure has been changed somewhat from year to year, but it is not considered necessary in this connection to give the exact composition from time to time, as the original records are available in the annual memoranda of the Rothamsted station. Plat 3 has been manured continuously, for the turnip crop only, with a complex mineral and nitrogenous manure.

Figure 22 shows the increases of the wheat crop every fourth year on plats 2 (1) and 3 (1), where the turnip crops were entirely removed and where either clover or beans were grown in the third year of the rotation; also on plats 2 (2) and 3 (2), where the turnip crops were entirely removed and where, in the third year of each course (excepting the first, 1850, when clover was grown), the land was left fallow.

Plat 2 in each series was fertilized with superphosphate of lime alone for the first nine courses and a complex mineral manure (without nitrogen) from course 10 onward.

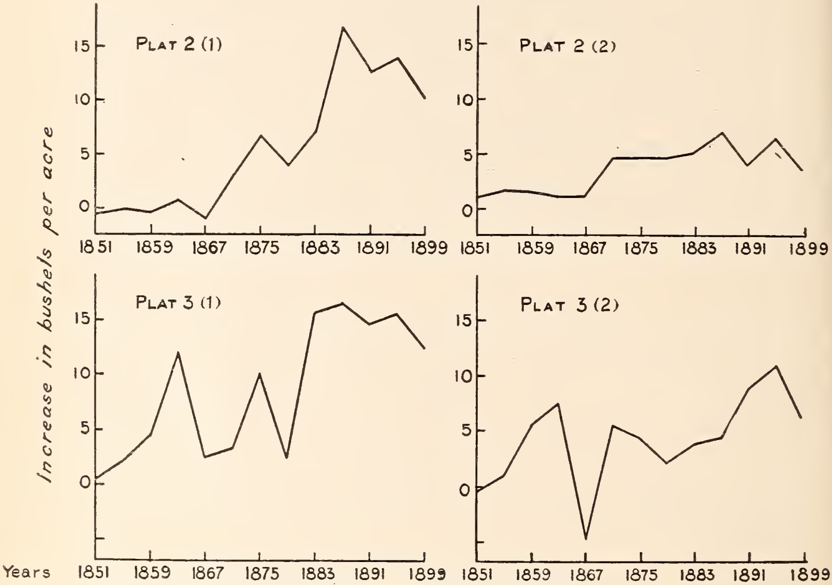

Fig. 22.

Plat 3 has been manured continuously with a complex mineral and nitrogenous manure.

Figure 23 shows the increases of the wheat crop every fourth year on plats 2 (3) and 3 (3) over the continuously unmanured plat 1, where the turnip crops were either fed off by sheep or cut and spread on the land, and where clover or beans were grown in the third year of the rotation; also on plats 2 (4) and 3 (4), where the turnip crops were either fed off by sheep or cut and spread on the land, and where every third year (except in the first course when clover was grown) the land was left fallow.

Plat 2 of both series was manured with superphosphate of lime alone for the first nine courses and a complex mineral manure (without nitrogen) from course 10 onward.

Plat 3 was manured continuously with a complex mineral and nitrogenous manure.

The records of these experiments extending from 1848 to 1899, inclusive, give 13 years in which wheat was grown in the rotation and give, therefore, 13 points from which to construct the diagram. It can readily be seen by a comparison of these diagrams with the long-time experiments with fertilizers on the Broadbalk field that with the great variation on individual plats from crop year to crop year that 13 points are too few to construct a reliable diagram. This is well illustrated in figures 24 and 25, in which

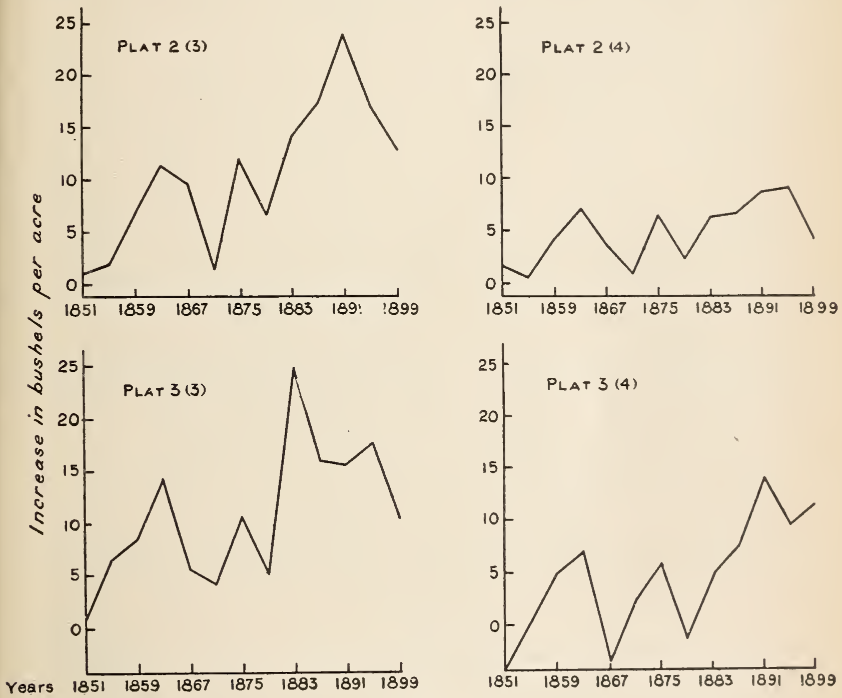

Fig. 23.

13 points have been taken every fourth year from some of the long-time experiments where wheat has been grown continuously, thus in effect having four-year periods beginning in 1851 or 1852, and comparing them with the more complete data on the figures representing each yearly crop increase during the entire life of the experiment.

Figure 24 shows the increase in yield of wheat per acre every fourth year on plat 7*a* from 1852 to 1896, inclusive; on plat 2 for every fourth year from 1851 to 1887, inclusive; on plat 9*b* every fourth year from 1852 to 1888, inclusive; and on plat 6*a* every fourth year from 1852 to 1896, inclusive. These should be compared with the complete data in preceding diagrams.

Figure 25 shows the increase in yield of wheat per acre every fourth year on plat 13*a* from 1851 to 1887, inclusive; on plat 18*a* for every fourth year from 1851 to 1899, inclusive; on plat 10*a* for every fourth year from 1851 to 1899, inclusive; and on plat 11*a* for every fourth year from 1851 to 1887, inclusive.

If these diagrams constructed from a few points taken at regular intervals of four years are compared with the diagrams showing the long-time records it will be seen that they offer no reliable guide as to the direction of the path as obtained in the long-time experiments where four times the number of points are available for the construction of the diagram.

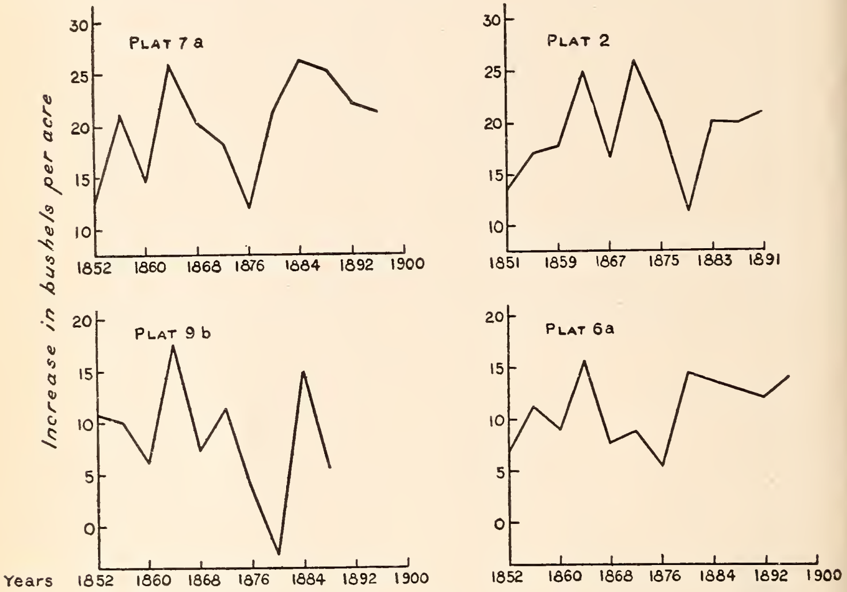

FIG. 24.

This point is perhaps still better illustrated in the three following diagrams.

Figure 26 shows the increase in yield of wheat per acre on plat 7*a* every fourth year, beginning in 1852. Each diagram is advanced one year in order to show the four different types of diagrams that it is possible to construct from the data, and it will be seen that they bear little resemblance to each other or to the diagrams in figure 17, from which they are taken.

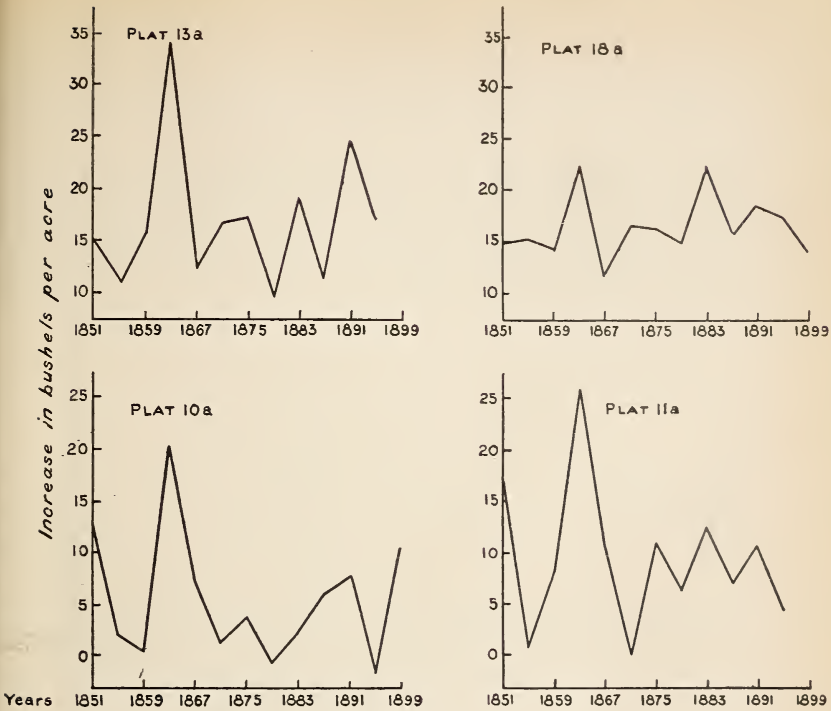
Increase in bushels per acre
PLAT 13a
35
30
25
20
15
10
1851
1859
1867
1875
1883
1891
1899
PLAT 18a
35
30
25
20
15
10
1851
1859
1867
1875
1883
1891
1899
PLAT 10a
25
20
15
10
5
0
Years
1851
1859
1867
1875
1883
1891
1899
PLAT 11a
25
20
15
10
5
0
1851
1859
1867
1875
1883
1891
1899

FIG. 25.

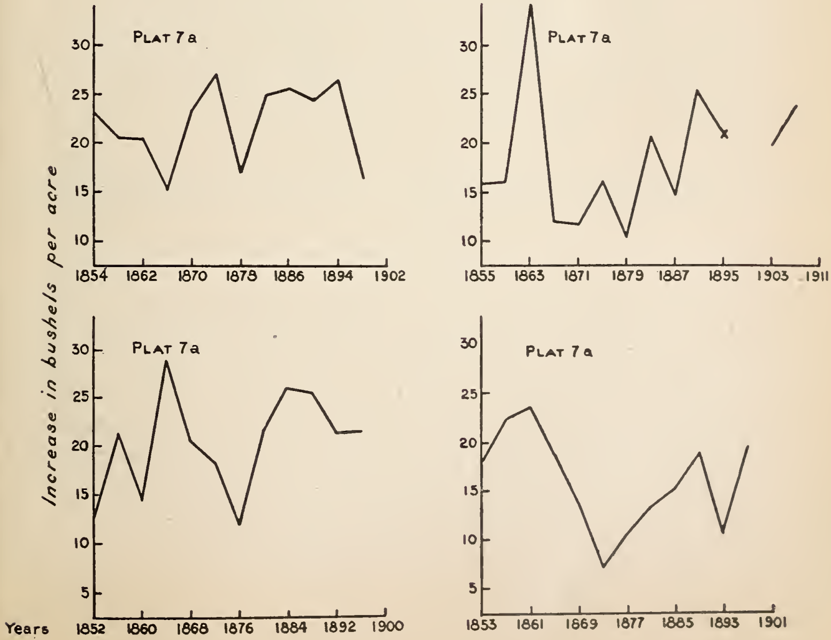
Increase in bushels per acre
PLAT 7a
30
25
20
15
10
1854
1862
1870
1878
1886
1894
1902
PLAT 7a
30
25
20
15
10
1855
1863
1871
1879
1887
1895
1903
1911
PLAT 7a
30
25
20
15
10
5
Years
1852
1860
1868
1876
1884
1892
1900
PLAT 7a
30
25
20
15
10
5
1853
1861
1869
1877
1885
1893
1901

FIG. 26.

Figure 27 shows the increase in yield of wheat per acre on plat 10*a* every fourth year, beginning in 1852. Each diagram is advanced one year in order to show the four different types of diagrams that it is possible to construct from the data. This should be compared with figure 13.

Figure 28 shows the increase in yield of wheat per acre on plat 11*a* every fourth year, beginning in 1852. Each diagram is advanced one year in order to show the four different types of diagrams that it is possible to construct from the data. This should be compared with figure 14.

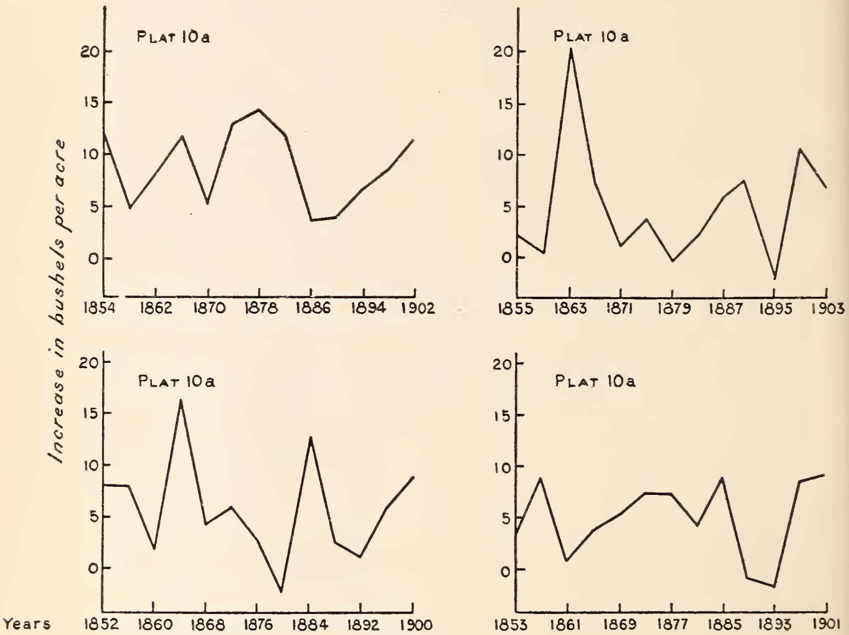

Fig. 27.

CONCLUSIONS.

It appears from the foregoing that the American experiment stations have reported the results of 3,227 tests with substances applied to wheat soils. The duplicate check plats show such wide variations that considerable latitude must be allowed in the interpretation of all results and the quantitative comparisons should not be given too great weight. The chances for increased production are greater with two or three fertilizers mixed than with a single substance, but on the average with the amounts of fertilizers used the increased crop at a value of 90 cents per bushel has not been worth as much as the cost of the fertilizing material.

It appears that the smaller applications of single fertilizers have given in general no less an increase than the larger amounts. The increases obtained from the more productive soils, based upon the yield of the unfertilized plats, appear to be no less than from the less productive soils, indicating an equal increase in crop for the same fertilizers on the average on good soils as on less productive soils. As these results have been obtained from a large number of soils with a considerable range in productivity over a number of years, these general conclusions, besides others of a qualitative value which can be drawn from the table, can, in the absence of any more specific knowledge of any particular soil, be safely followed as a guide to the immediate selection of fertilizers for a wheat soil. The data contained in the station reports do not permit one to judge accurately of the cumulative effect of the continued use of fertilizer on the same soil for a long series of years. Even the 15-year experiments at the Ohio Station and the 25-year experiments at the Pennsylvania Station leave some doubt as to this point, and it has been necessary, in order to clear up this doubt and to weigh the relative efficiency of the single tests made at most of the stations, to go to the long-time series of plat experiments which have been carried on at the Rothamsted Station.

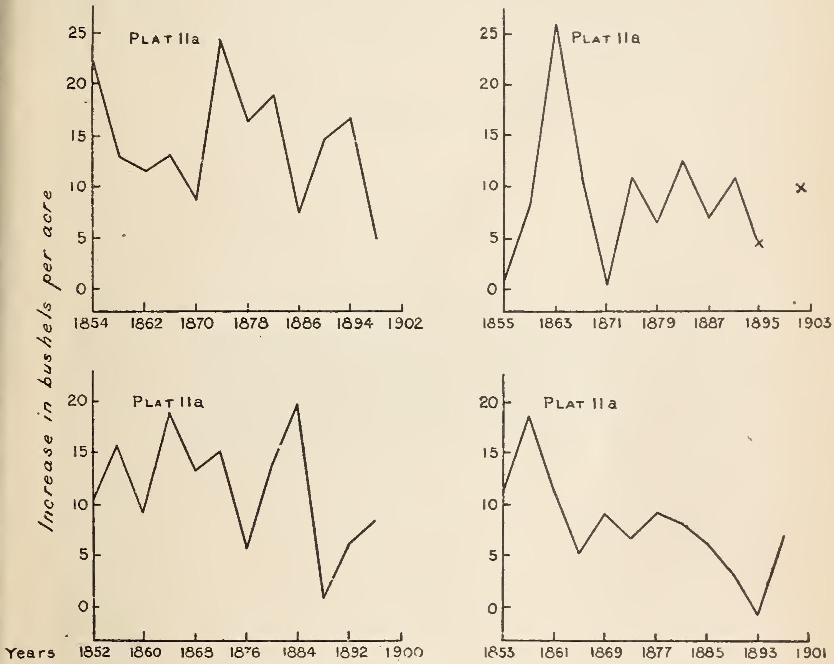

Fig. 28.

A study of the curves of the plat experiments at Rothamsted which have been given in this report seems to indicate in general, with the exception of the plat which has received stable manure, that there is no evidence to show a cumulative effect obtained by long-continued use of the ordinary fertilizing materials. It appears further that the yearly variations of the differences due to the fertilizing materials are as great upon the same soil whether we take the Ohio, Pennsylvania, or the Rothamsted results, as the variations reported by the experiment stations upon different soils, from which it may be inferred that the general results of the American experiments, covering over three thousand observations, can be accepted as a reliable indication of the relative efficiency of fertilizing materials where these results are based upon a reasonable number of tests.

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